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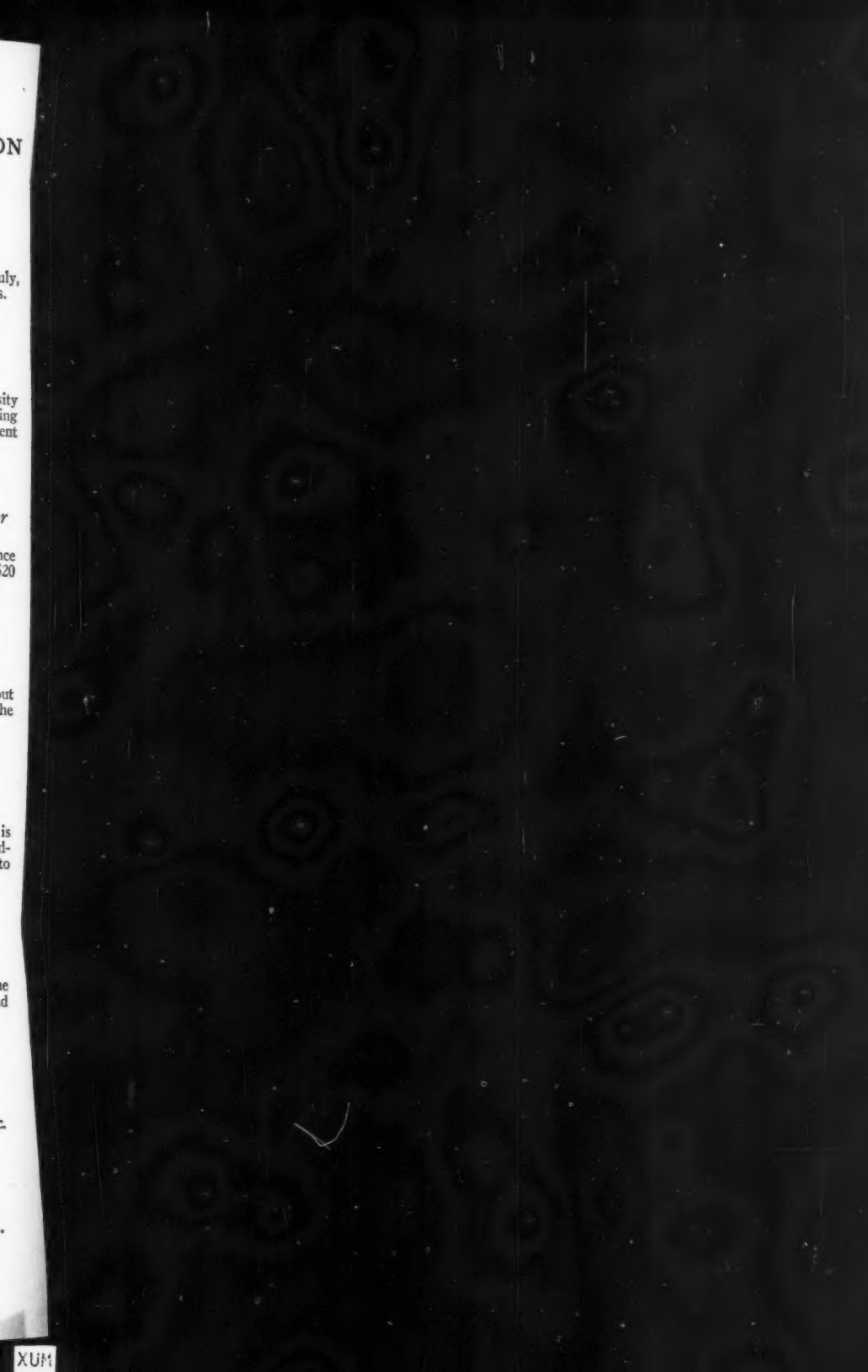

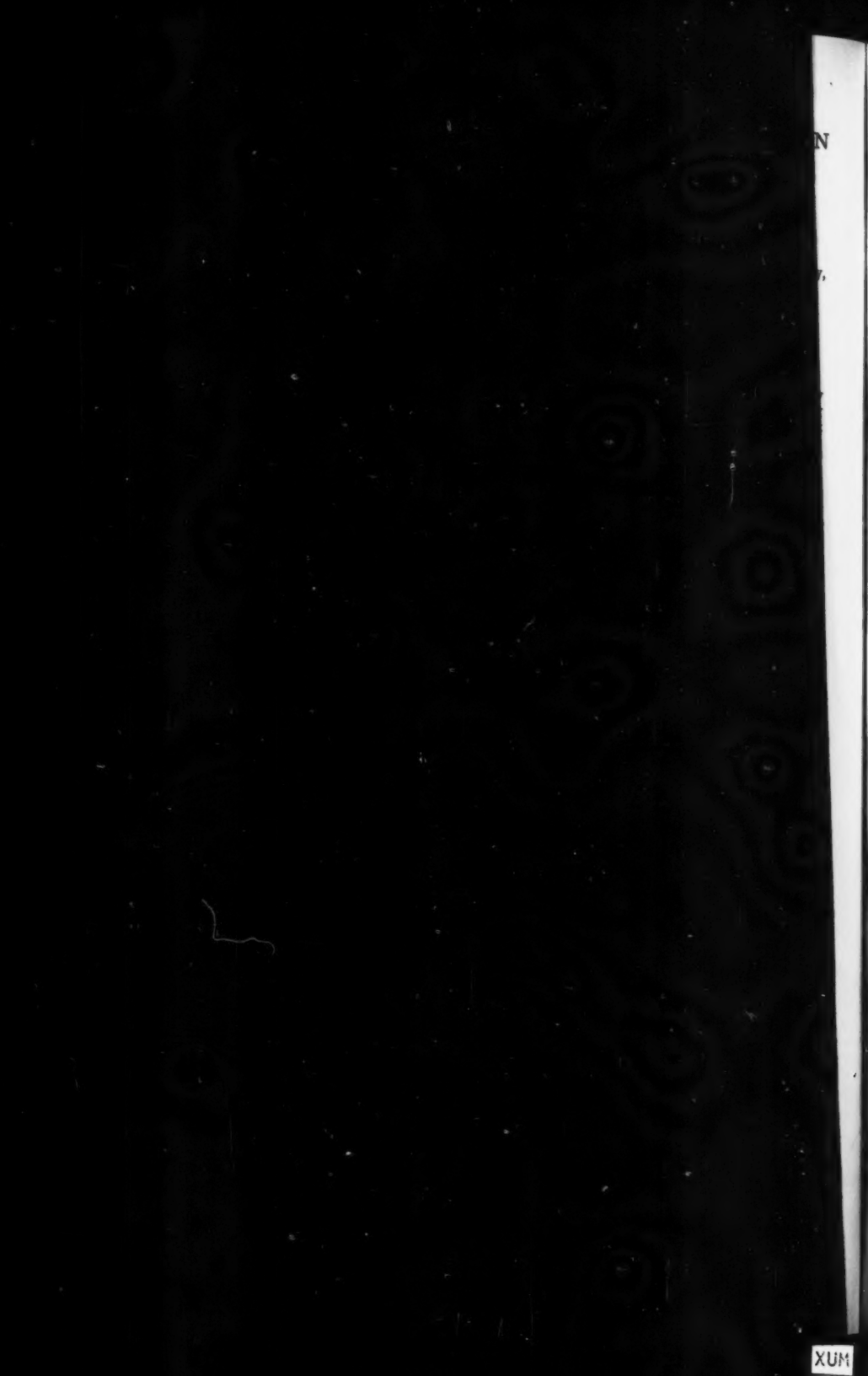

Journal of
Experimental Psychology

VOL. 33, NO. 3 SEPTEMBER, 1943

THE NEURAL MECHANISMS OF MOVEMENT VISION AND OPTIC NYSTAGMUS

BY KARL U. SMITH*

Southern Signal Corps School, Camp Murphy, Fla.

AND

MARJORIE BRIDGMAN

Columbus, Ohio

A. INTRODUCTION

The cerebral cortex in mammals, although indispensable in determining certain special aspects of movement vision, has only secondary significance in the mediation of optic reactions produced by movement of compound patterns in the visual field. Loss of the visual cortex in the guinea pig and cat does not deprive these animals of their ability to respond to moving visual patterns. Rather, it causes their reactions of optic nystagmus to become more regular and less susceptible to extinction (Smith, **7**). In the cat, however, a specific deficit in nystagmus and movement vision appears following removal of the visual cortex. Ordinarily, the cat displays optic pursuit to movement of isolated patterns in the visual field as well as to moving compound patterns, in contrast to the guinea pig in which reactions occur only to movement of compound visual patterns. Loss of the visual cortex in the cat renders it incapable of responding to isolated moving patterns (Smith and Warkentin, **9**). There appear to be, therefore, two sensory mechanisms of movement vision in the cat, one related to the fixation and discrimination of relatively isolated patterns in the visual field and another based on the fixation and pursuit of compound pattern differences. The former of these mechanisms, depending primarily upon capacities of pattern vision of a discrete sort, appears to be determined almost exclusively by the optic projection centers of the cortex, while the latter is maintained

* On leave from the Laboratory of Psychology, The University of Rochester.

by the visual centers below the cortex, and is related to processes of spatial and temporal summation of excitation in these centers. Since the guinea pig does not normally display nystagmic reactions to isolated moving stimuli, the complete removal of the cerebral cortex produces no definitive change in the nature of its movement vision as manifested by optic nystagmus.

In addition to the cortical-subcortical division of movement vision capacities noted in the cat, a further division of the sensory mechanisms of movement vision and optic nystagmus may be distinguished in reptiles, birds, and some rodents, namely, a bilateral differentiation of function in the subcortical systems of movement vision. Mowrer (**6**) has shown that the pigeon (the visual system of submammalian forms is largely limited to subcortical centers), when one eye is covered, displays optic nystagmus to a series of stripes moving in the horizontal plane only when the stripes move in a direction toward the side of the covered eye. The nystagmus does not occur when the movement of the stripes is toward the side opposite that on which the eye is covered. As will be shown below, this same bilateral separation of the subcortical mechanisms underlying nystagmus and movement vision is found in the guinea pig, and possibly also in the cat.

It is proposed in this paper to describe experiments which clarify further the divisions of labor existing in the central visual system for the mediation of various aspects of movement vision. Since previous study has shown that the optic nystagmus of the guinea pig is primarily determined by subcortical processes, it remains to show in what manner the lower visual centers are organized for the control of reactions to patterns moving in different directions.

B. Procedure

The apparatus used in this study has been described in detail in previous experiments (**8**). A partly spherical rotating drum, composed of 50 equally spaced white ribs, provides the moving stimuli used in testing the animals. The drum is provided with controls which permit accurate variations in the speed of movement of the stripes and reversal of direction of the movement.

During experimentation, the animal is arranged in a box-holder and supported so that its head is located at the center of the drum. The head nystagmus elicited by the movement of the stripes is recorded mechanically on an ink-writing polygraph by means of a fine silk thread leading from the animal's nose to a writing-lever. At the beginning of an experimental period, the room is darkened and the drum is set in motion at a predetermined speed. The polygraph is then turned on, and, after a short pre-stimulation record of the animal's movements has been secured, the light inside the drum is switched on for a period of about one minute. A short post-stimulation record is thereafter secured. After a rest period of several minutes, similar records are made at different speeds and directions of movement. Ordinarily, the animal is first tested at slower speeds of movement and the velocity of the drum thereafter increased in steps until a terminal threshold of response is reached. Observations on normal and operated animals are carried out in the same fashion.

C. Animals and Operations

Fifteen adult guinea pigs were used in the experiment. Three of these animals were employed in investigating the effect of deprivation of vision in one eye upon the responses of the animals to movement stimulation. After preoperative testing, lesions were made in the left superior colliculus of five animals, in the right superior colliculus in three animals, and in both colliculi in five animals. The bilateral operations were performed in one stage with one exception, in which case destruction of the right superior colliculus was carried out first. In three cases with unilateral collicular lesions, removal of the occipital areas of the cortex was carried out at a later time.

The operations on the midbrain of the guinea pig were carried out by exposure of the occipital areas of the brain and elevation of the occipital lobes of the cerebral cortex in order to permit a direct approach to the roof structures of the quadrigeminal bodies. The roof tissue of the colliculus was removed with a glass suction-pipette. Care was taken during this procedure not to injure the cortical tissue.

When the experimental observations on the animals were completed, they were killed and the brains perfused with formalin. The brains were thereafter dehydrated, embedded in celloidin, sectioned, and stained in thionin. Projection drawings of the destruction in the midbrain were made to determine the approximate extent of the lesions. Among the animals with lesions of the left colliculus, the posterior half of the body was destroyed in Subjects 4 and 5, and all of the body except for a narrow strip in the anterior part was destroyed in Subjects 1, 2, and 3. The lesions of the right colliculus were extensive but not complete in Subjects 6 and 7, and included only the posterior third of the structure in Subject 8. The bilateral lesions in four animals (Subjects 10, 11, 12, and 7) destroyed the cells of both colliculi over the posterior two-thirds of each side, but left intact the anterior regions. In the other animal of this group (Subject 9) the lesion was limited to the posterior half of each colliculus. Subjects 7 and 12 had the most extensive lesions of this group. Injury to structures lying below the roof-nuclei occurred in two cases (Subjects 3 and 10).

D. Results

1. *The nature of optic nystagmus in the guinea pig when one eye is covered.*

Three animals (Subjects 13, 14, and 15) were employed in this part of the experiment. They were prepared for observation by covering one eye with a small piece of absorbent cotton and adhesive tape. After records had been obtained with the one eye covered, the experiment was repeated when the animals were deprived of vision in the other eye. Normal control observations were made on all three animals.

Part A of Fig. 1 illustrates the character of the guinea pig's reactions to the movement of the striations of the drum. Six records are shown in the figure, three taken when the stimuli were moving to the animal's right, and three when the lines were moving to its left. For each direction of movement, reactions at three velocities are shown, namely, velocities of 5, 10, and 25 stripes passing per sec.[1] Each record contains a time line, indicating the time in seconds (the top line of each record), a record of the onset and termination of the stimulus light in the drum, and a response line (bottom line). De-

[1] Hereafter the term stripes per sec. will be used to designate velocity of the drum. Since the drum contained 50 white stripes, a speed of 5 stripes per sec. would be equivalent to 0.1 revolution of the drum per sec., or 36 degrees per sec. In making observations, the velocity of the drum was ordinarily increased in steps of 5 stripes per sec.

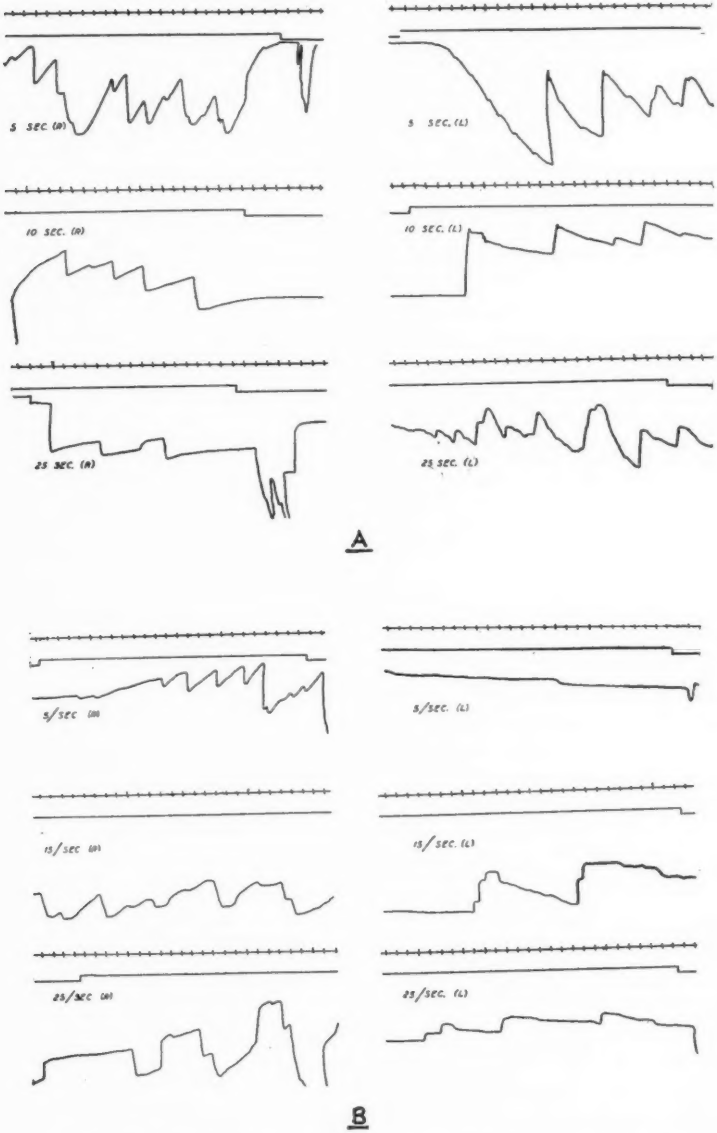

FIG. 1. Optic head nystagmus in the guinea pig elicited by rotating stripes

Part A: Reactions of Subject 6 when in a normal state. Part B: Reactions of Subject 6 with the right eye covered.

Each record contains a time line indicating seconds, a stimulus line, and a response line, on which deflections upward represent reactions made to the right. Velocity and direction of the moving striations are indicated on each record.

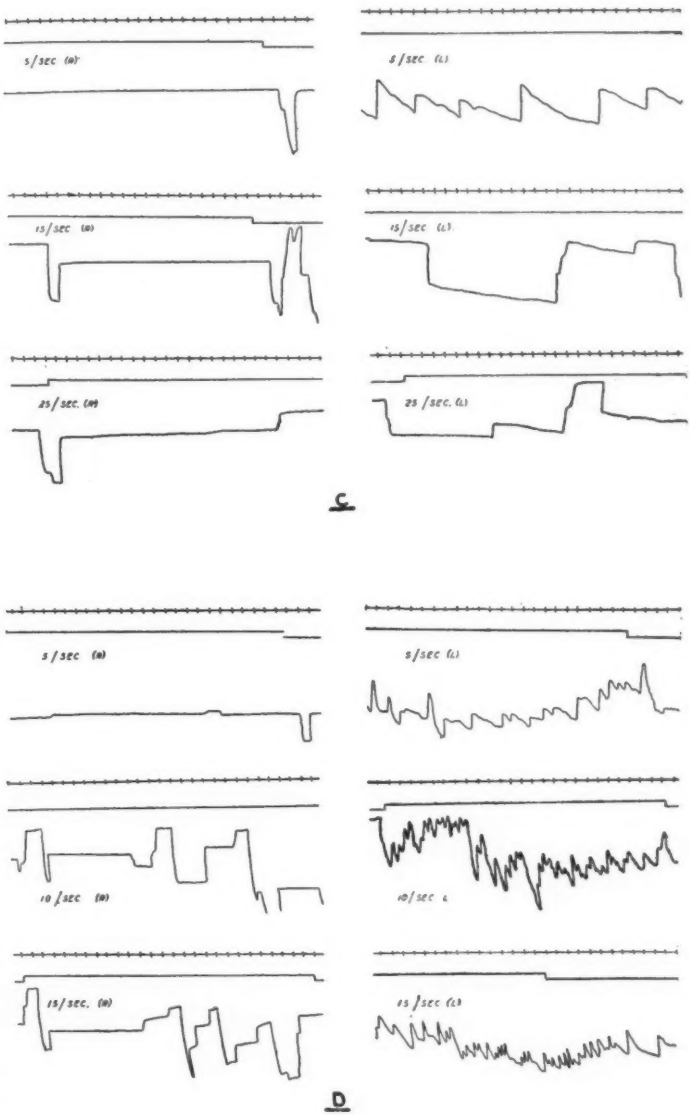

FIG. 1. Optic head nystagmus in the guinea pig elicited by rotating stripes

Part C: Reactions of Subject 6 with the left eye covered. Part D: Reactions of Subject 6 following removal of the right superior colliculus.

Each record contains a time line indicating seconds, a stimulus line, and a response line, on which deflections upward represent reactions made to the right. Velocity and direction of the moving striations are indicated on each record.

flections upward of the stimulus line indicate the point at which the light inside the drum was turned on, while deflections downward represent the termination of the stimulus. Deflections upward of the response line represent reactions made to the right, deflections downward, reactions made to the left. These six records illustrate the typical reactions of optic head nystagmus of the guinea pig when its visual environment is rotated. The responses made by the animal duplicate the general form of eye nystagmus produced by the same kind of stimulation in animals with highly mobile eyes. In the guinea pig, the movement of the visual field produces a forced pursuit movement of the head in the direction of the movement of the visual field, which is followed abruptly by a rapid saccadic movement of the head which returns the gaze to a new point of fixation. The pursuit and saccadic phases of the nystagmus may be seen clearly in all the records shown in the figure. The responses of this animal at the different velocities of movement vary considerably in amplitude and frequency, as well as in regularity. At the slowest speed of movement of the environment, the reactions are slow and of rather high amplitude. In the record showing the reactions to the left at the slowest speed, one may observe small nystagmic movements, which correspond to the eye nystagmus of the animal, superimposed upon the larger head nystagmus. As the speed of rotation of the drum is increased, the extent of the pursuit movements is decreased while their frequency, in some instances, may be increased. The animal on which these records were taken responded to speeds higher than 25 stripes passing per sec.

Part B of Fig. 1 describes the change in the reactions of the guinea pig when vision in the right eye is temporarily eliminated. Responses to the right, i.e., toward the side on which the eye is covered, are reduced in amplitude and changed in regularity, but they persist at all three velocities of movement of the visual field. The reactions involving pursuit in the opposite direction, i.e., toward the side of the seeing eye, are practically abolished at the slower velocity and they appear as separate irregular jerks, without regular pursuit, at the higher velocities. When the left eye of the animal is covered, permitting vision in only the right eye, these relations are reversed (Part C of Fig. 1). Under these conditions, the pursuit reactions toward the covered eye appear in regular form at a velocity of 5 stripes per sec., and irregularly at the higher velocities. Pursuit reactions toward the seeing eye, however, are abolished altogether. Two records in this group, those taken at velocities of 5 and 10 stripes per sec. toward the right, illustrate a phenomenon often seen in the guinea pig when it is deprived of vision in one eye and the drum rotated toward the seeing eye. Notwithstanding the fact that the

animal fails to respond to movement of the stripes during rotation of the drum, termination of the stimulus causes an abrupt saccadic jerk or a series of such movements. The importance of this fact will be considered later, for it seems to indicate that while the neural mechanisms of pursuit are unilaterally abolished by covering one eye, the saccadic reactions, mediated by a different neural mechanism, are not disturbed.

For purposes of comparison, a set of records (Part D of Fig. 1) are shown which were obtained from Subject 6 after an operative lesion had been made in the right superior colliculus. The lesion took in almost the entire collicular body, although some few cells remained along the anterior region of the roof of the midbrain. It will be seen that destruction of the right colliculus has the same general effect as covering the left eye, but an effect which is more clear-cut. With the right colliculus destroyed, pursuit responses toward the right are abolished almost altogether, but those toward the left are increased in frequency at all velocities. It is to be noted that in this case also there are produced, upon termination of rotation of the drum toward the deficient side (in this case the right), saccadic after-movements similar to those observed in Part C.

The elimination of one eye produces a uniform effect in different guinea pigs. Table I summarizes the results secured on three guinea

TABLE I

THE NUMBER OF RESPONSES IN 15 SEC. BEFORE AND AFTER COVERING ONE EYE (THREE SUBJECTS)

Stripes per Sec.	Stripes toward Open Eye				Stripes toward Closed Eye			
	Normal	Exper.	Diff.	t	Normal	Exper.	Diff.	t
5	7	1	6	10.4	7	8	−1	1.4
10	10	1	9	3.4	10	3	7	2.4
15	4	1	3	3.8	4	4	0	0.5
20	3	0	3	4.0	3	4	−1	1.7
25	4	1	3	4.0	4	4	0	0

pigs in which the right and left eyes were covered in different observations, as compared with responses of the animals when under normal conditions. The data summarized in the table represent means for the three animals, calculated from the maximum number of responses made in fifteen sec. during each period of stimulation. The part of each record containing the most frequent and regular movements was chosen in order to make this count. In the table, the mean responses elicited when the drum moved toward the open eye and toward the closed eye are compared with the mean responses which

occurred both to the right and to the left when vision was permitted in both eyes. The values of t given in the table indicate a definitely significant decrease in responses when the stripes were moving toward the open eye for the lowest velocity of movement. At the higher velocities, the statistical significance of the decrease is questionable, due to the small number of subjects, but the decrease appeared consistently, without exception, in each of the subjects. With movement of the drum toward the closed eye, there were no significant changes in response frequency. These data indicate what has already been pointed out, i.e., when one eye of the guinea pig is covered, pursuit responses made with reference to movement toward the open eye are markedly reduced, although not completely abolished, while those made to movement of the visual environment toward the closed eye, although altered in magnitude and regularity, are not as significantly affected.

These observations may be summarized by saying that in the guinea pig the pursuit phase of optic nystagmus for a given direction of rotation is determined predominantly by one eye. Horizontal pursuit movements toward the right are controlled mainly by the left eye, and horizontal pursuit movements to the left, by the right eye. Both eyes play some rôle in each direction of movement, for deficiencies of pursuit in both directions occur when one eye is covered. The saccadic movement of optic nystagmus is controlled by neural mechanisms distinct from those determining the pursuit phase. This is proved by the occurrence of saccadic after-movements in the guinea pig with one eye covered, which often occurs after a period of stimulation which has produced no pursuit reactions.

2. *The effect of unilateral lesions of the superior colliculus upon movement vision and optic nystagmus.*

Eight animals were used in this part of the experiment. Lesions were made in the right superior colliculus in three animals, and in the left colliculus in five animals. None of the lesions involved all of the roof cells of the midbrain, but in all but two of the cases, the destruction extended over more than half of the posterior aspect of the colliculus.

The nature of optic nystagmus in the guinea pig after this operation is shown in Fig. 2, which presents results obtained on two animals, one with the right colliculus and one with the left colliculus partly destroyed. The records of the animal shown in Part A, normal records for which have been given in Fig. 1, are typical of all the guinea pigs in which an extensive lesion was made in one superior colliculus. Following this operation, the animal fails to show clear-cut nystagmus movements when the drum is rotated toward the side on which the operation was performed. Since the

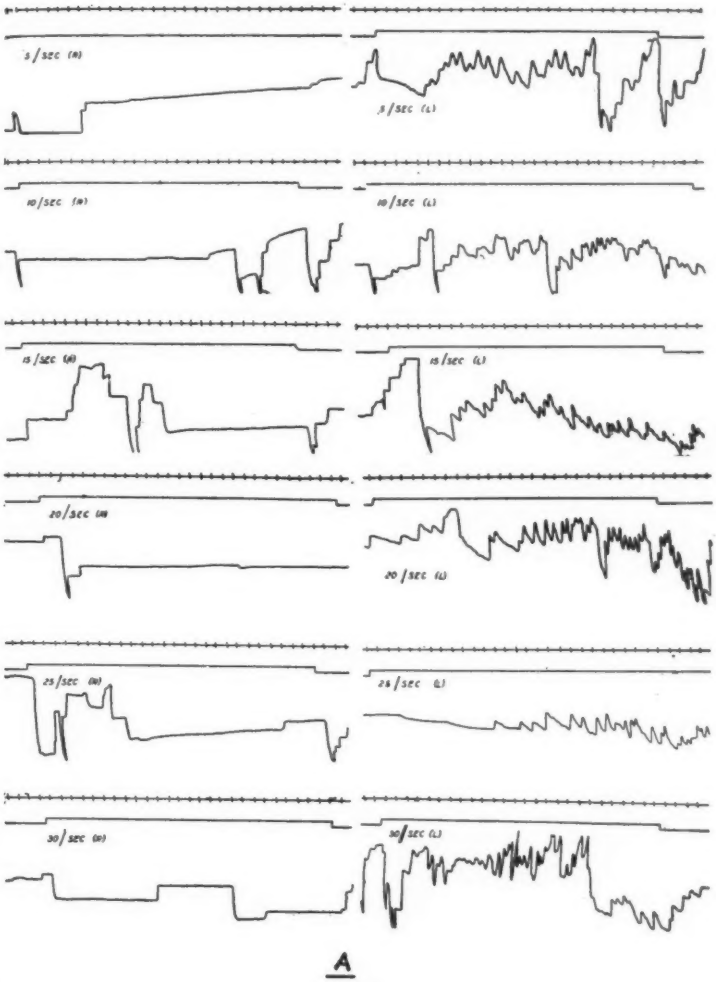

FIG. 2. Optic head nystagmus following unilateral collicular lesions
Part A: Reactions of Subject 6 following destruction of the right colliculus.

right superior colliculus was destroyed in this animal, rotation of the drum to the right elicits practically no responses. Parts B and C of Fig. 2 illustrate further the effects of the removal of one colliculus. Part B shows normal records for Subject 4, and Part C, records which were obtained after destruction of the left colliculus, showing marked reduction in frequency of pursuit movements to the left.

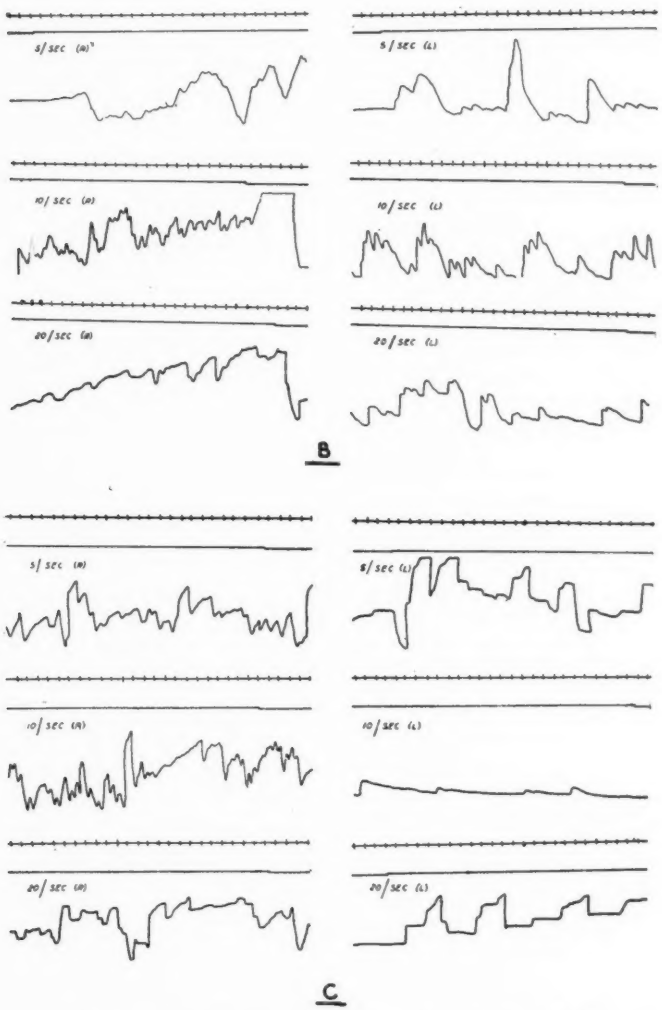

FIG. 2. Optic head nystagmus following unilateral collicular lesions

Part B: Normal reactions of Subject 4. Part C: Reactions of Subject 4 following destruction of the left colliculus.

The general character of the reactions made by animals with unilateral lesions is noteworthy. The responses made when the drum turns toward the side opposite the lesion are ordinarily greatly increased in frequency at all velocities. Under such circumstances

the animal may make as many as three to four nystagmus reactions per sec. (Note the responses to the left in Subject 6 at velocities of 15, 20, and 30 stripes per sec.) Furthermore, after-nystagmus movements following rotation toward the side opposite the lesion are greatly exaggerated subsequent to the operation. Such post-stimulatory reactions are clearly seen in the postoperative records in both Figs. 1 and 2. Record D in Fig. 1 illustrates that these reactions may continue for many seconds after the stimulus has ceased. The reactions toward the deficient side are well illustrated by the records of Subject 4 (Part C of Fig. 2), an animal with a lesion of the left colliculus. Postoperatively, this animal still displayed at times rudimentary pursuit movements to rotation to the left. The deficient pursuit movements, however, were set off into groups by the periodic occurrence of saccadic reactions of high magnitude, which are especially marked at velocities of 5 and 20 stripes per sec. to the left in the postoperative record. In some cases the animals with unilateral lesions displayed marked saccadic after-movements following rotation toward the deficient side. Such responses may be seen clearly in some of the records of responses to the right in Subject 6 (Part A of Fig. 2).

Table II summarizes the data secured on eight guinea pigs before

TABLE II

THE NUMBER OF RESPONSES IN 15 SEC. BEFORE AND AFTER UNILATERAL REMOVAL OF THE COLLICULUS (EIGHT SUBJECTS)

Stripes per Sec.	Stripes toward Side of Lesion				Stripes toward Side Opposite Lesion			
	Preop.	Postop.	Diff.	t	Preop.	Postop.	Diff.	t
5	7	4	3	2.0	7	11	−4	3.4
10	6	2	4	3.3	8	10	−2	0.7
15	3	1	2	2.0	6	7	−1	0.6
20	5	1	4	3.5	4	6	−2	1.0
25	3	1	2	3.7	4	4	0	0.2

and after unilateral operations on the superior colliculus. Again, the nystagmic responses have been counted over a period of 15 sec. in that section of each record showing the most frequent reactions, and the number of responses of all animals averaged for the different velocities indicated in the table. The individual values are combined according to whether they are responses made toward the side of the lesion, or toward the side opposite the lesion. Differences between preoperative and postoperative means and the corresponding values of t appear in the table. The animals with unilateral collicular lesions showed a significant decrease in the number of

nystagmus responses when the drum rotated toward the side of the lesion at three velocities, 10, 20, and 25 stripes per sec., and decreases of questionable significance at the remaining two velocities. In contrast there was after operation a consistent mean increase in frequency of response toward the side opposite the lesion. In one case, at a velocity of 5 stripes per sec., the increase was significant.

These changes in the nystagmic responses of the guinea pig after lesions of the colliculus are permanent in animals with extensive operations, while animals with less extensive lesions appear to show some recovery after a period of one to two weeks. The results as presented apply to the reactions of the animals following a period of postoperative recovery of two to three weeks, after which time there is little observable change in the deficiencies which have been described.

On the basis of the records described and the tabulated data presented, it may be stated definitely that unilateral lesions of the superior colliculus produce notable defects in movement vision and optic nystagmus when the movement of the visual environment is toward the side on which the lesion of the colliculus has been made. At the same time, the responses to movement in the reverse direction, toward the side opposite the lesion, are increased in frequency and post-stimulatory persistence by the operation. Animals with lesions of the left colliculus respond poorly or not at all with movement of the drum to the left, but postoperatively their responses to the right become more regular and frequent. Those with lesions of the right colliculus respond poorly or not at all to rotation of the environment to the right, but their reactions to the left become more frequent and regular. The implications of these observations seem to be that optic nystagmus with pursuit toward the right is controlled predominantly by the right superior colliculus, which appears to be indispensable for normal reactions, while reactions with pursuit toward the left are mediated predominantly by the left colliculus, which is indispensable for the appearance of the reactions in normal form.

Inhibitory mechanisms are involved in the normal neural balances between the centers controlling optic nystagmus. This is proved by the fact that there is a significant increase in the frequency of the reactions to the left when the right colliculus is removed and toward the right when the left colliculus is injured. Whether this balancing of functions exists between the two colliculi directly or through other centers is a matter of conjecture.

3. *Effect of bilateral lesions of the superior colliculi upon optic nystagmus.*

Five animals with bilateral injury to the superior colliculi were investigated. The effect of the bilateral operation, in general,

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amounts to what might be expected on the basis of the results secured on the animals with the unilateral operations. In Parts A and B of Fig. 3 are shown the results obtained on Subject 7 before and after an operation in which both colliculi were destroyed except for the most anterior fringe of each body. Nystagmus reactions in this animal, which are clearly demonstrated at the different velocities prior to operation, are practically absent subsequent to operation at velocities above 5 stripes per sec.

Table III summarizes the results secured on the five animals with bilateral lesions. This table is arranged in the same general manner as those previously discussed, giving mean differences between preoperative and postoperative frequency of response at the various velocities. The data show that after operation the frequency of

TABLE III

THE NUMBER OF RESPONSES IN 15 SEC. AFTER BILATERAL REMOVAL OF THE COLLICULI (FIVE SUBJECTS)

Stripes per Sec.	Preop.	Postop.	Diff.	t
5	6	2	4	4.4
10	6	1	5	2.8
15	3	2	1	1.1
20	4	1	3	3.1
25	4	1	3	3.9

nystagmic reactions is reduced at all five velocities, for four of which the reduction is significant. After the bilateral operation, two of the animals employed displayed no nystagmus whatsoever at any of the five velocities of movement.

4. *Optic nystagmus after combined lesions of the visual areas and one superior colliculus.*

For purposes of demonstration and control, three animals were subjected to operations involving removal of the occipital areas of the brain after one colliculus had already been injured. The results on these animals confirm previous observations in showing that the destruction of the occipital areas of the cortex in the guinea pig with one colliculus destroyed—which accordingly shows deficient reactions with movement of the visual environment toward the side of the collicular lesion and increased frequency of response with movement of the environment toward the side opposite the collicular lesion—tends to make more regular the responses of the animal to both directions of movement. Responses toward the deficient side, if they are present at all after the collicular operation, appear more uniform following the occipital lesion, as do also those in the opposite

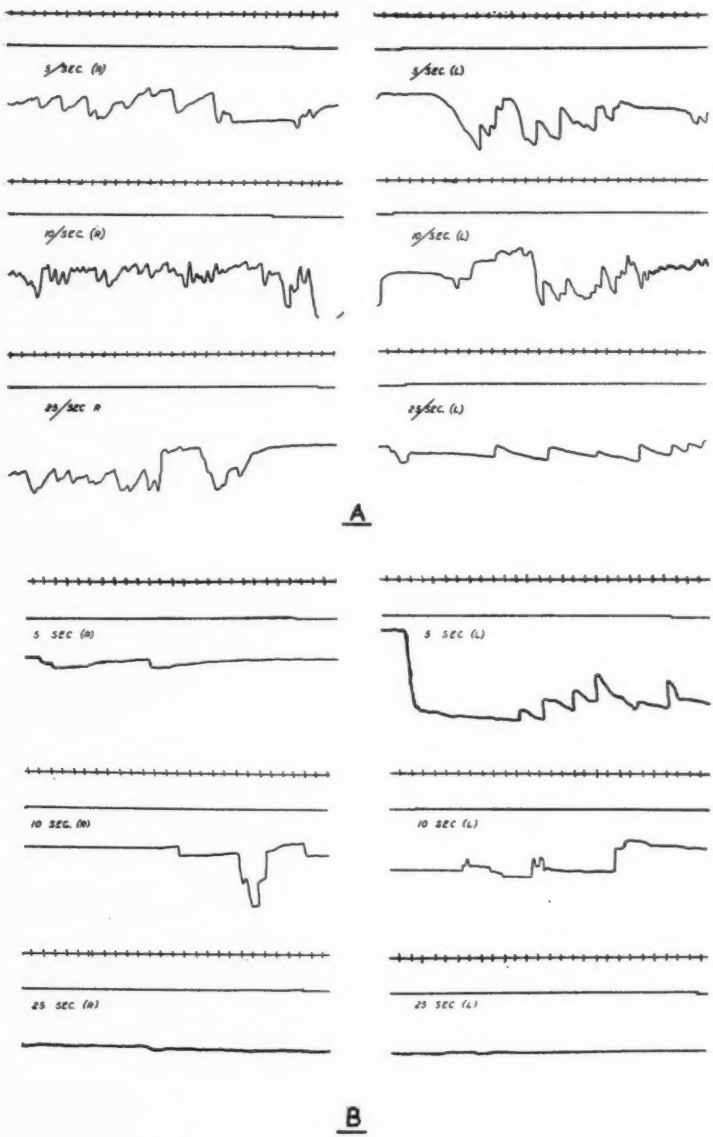

FIG. 3. Optic head nystagmus following bilateral collicular lesions

Part A: Normal reactions of Subject 7. Part B: Reactions of Subject 7 following destruction of both colliculi.

direction which have already been increased in frequency by the unilateral collicular lesion.

5. *Comparison of the nystagmic reactions of the normal guinea pig with one eye covered, of the guinea pig with unilateral injury of the superior colliculus, and of the guinea pig with bilateral injury of the superior colliculus.*

The effects of the different procedures described above upon the nystagmic reactions of the guinea pig may be discussed with reference to the efficiency of the nystagmic movements in the pursuit of the lines of the drum traveling at different velocities. A measure of efficiency of optic nystagmus may be secured by using an index based upon the number of lines passing a point in the visual field of the animal during each response. This value, which we refer to as the nystagmus index, is obtained by dividing the number of stripes passing per sec. by the average number of responses per sec., computed from the total responses made during the fifteen sec. period of maximal response frequency. When the efficiency of the pursuit movements in following the stripes of the drum is expressed in terms of this index, an index value of 1 indicates that the animal shows perfect coördination in visual pursuit, giving one nystagmus response for every line which crosses the visual field. Inability of the animal to 'keep up' with the number of stripes gives an index value greater than 1.

Fig. 4 summarizes the main groups of data in the form of graphs of the nystagmus index, plotted as a function of stripe velocity. Graphs A and B show the results for the animals in which one eye was covered, compared with the data secured when normal vision was allowed. Similar comparisons are shown in Graphs C and D which represent the data for the animals with unilateral lesions of the superior colliculus. In Graph E the preoperative and postoperative nystagmus indices at different velocities of the drum are given for the animals with bilateral lesions of the superior colliculus. It is to be noted that the ordinate of the curves for the animals with the bilateral lesions is compressed in comparison to ordinates of the other graphs. In the animals in which one eye was covered, the efficiency of pursuit movements toward the closed eye is changed only slightly (Graph A). Pursuit movements toward the open eye, however, are greatly modified, with the greatest deficiencies appearing at the lower velocities, since it is at these speeds that the greatest proportionate increases in the nystagmus index are found (Graph B). At a velocity of 5 stripes per sec., the animals displayed normally, on the average, one response for every 5 stripes that passed across the visual field, but after covering one eye, the number of stripes passing per response

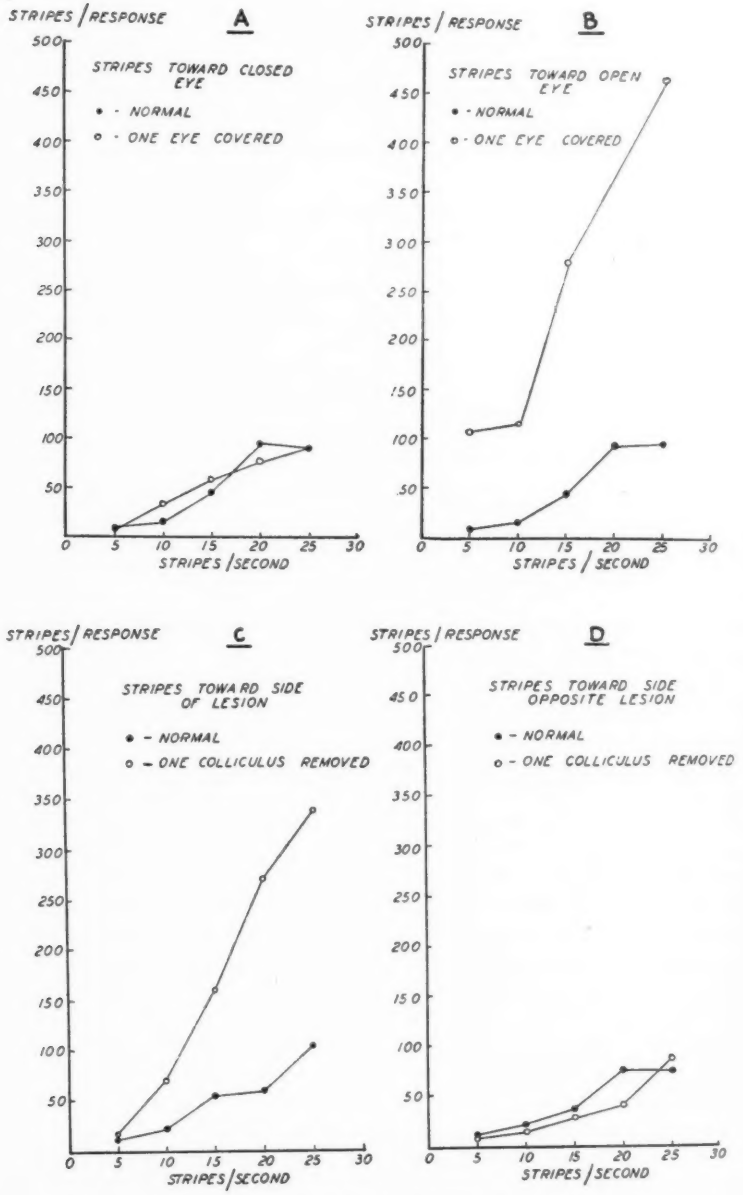

FIG. 4. The nystagmus index as a function of stripe velocity

The nystagmus index is a value expressing the mean number of lines passing a point in the visual field during each response of the animal.

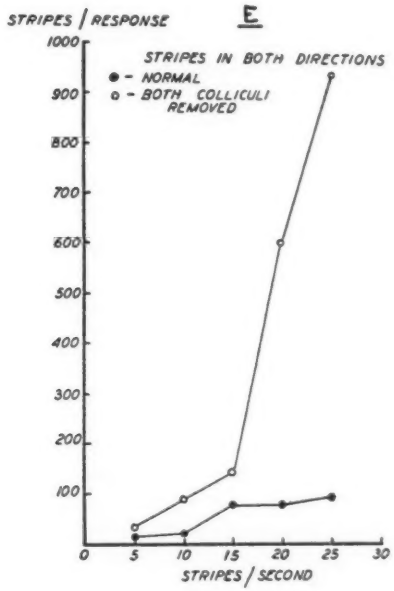

FIG. 4. The nystagmus index as a function of stripe velocity

The nystagmus index is a value expressing the mean number of lines passing a point in the visual field during each response of the animal.

was increased to about 100 when the movement of the drum was toward the open eye. The nystagmus index was increased by a factor of approximately 5 at a velocity of 25 stripes per sec. As shown by Graphs C and D, the nystagmus index is not increased, but rather consistently decreased when animals with unilateral collicular lesions are stimulated by stripes moving toward the side opposite the lesion. It is increased significantly, however, for stripes moving toward the side of the lesion, except at the lowest velocity of 5 stripes per sec. It is readily seen that covering one eye produces a greater disturbance in the nystagmus of the guinea pig than does the unilateral destruction of the colliculus. This is no doubt explained by the fact that the operations did not abolish all of the cells of the colliculus. In Graph E the nystagmus indices of normal animals are compared to those of the same animals after bilateral lesions of the superior colliculi. This operation greatly increases the nystagmus index at the higher velocities of rotation, while at lower speeds of movement there is a consistent but less marked increase in the index.

Of all the procedures investigated in this study, the bilateral removal of the colliculi was most effective in decreasing the efficiency of the nystagmus at high speeds of movement of the drum.

E. Discussion

1. *The neural mechanisms of optic nystagmus.*

The present results are clear enough in their general nature. The optic nystagmus of the guinea pig, which is elicited by movement of a stimulus pattern of compound visual contours (the type of pattern essential to produce the responses in the guinea pig), is based neurologically upon specific peripheral and central mechanisms possessing inherent balanced relations with one another. Peripherally, responses made to movement of the visual pattern in one direction of rotation in the horizontal plane are controlled almost exclusively by one eye. The left eye controls the responses with pursuit to the right; the right eye controls responses with pursuit to the left. Centrally, the next important level of control is the retinal-collicular system. The right colliculus is indispensable for the responses with pursuit to the right, the left colliculus, for pursuit to the left.

Besides these retinal and central mechanisms of direct control of the responses, integrative balances between the two superior colliculi, and between the cerebral cortex and the superior colliculi, are important in determining characteristics of the responses in the different directions of movement. While the right superior colliculus determines primarily the responses to the right, the left superior colliculus normally has an inhibitory control upon these reactions, for, in the absence of the left colliculus, the responses with pursuit to the right show increased frequency, greater persistence of after-nystagmus, and lowered susceptibility to extinction by continuous rotation. As shown in a previous study (Smith, **8**), the same inhibitory relations are found to exist between the cerebral cortex and the superior colliculi, such that each cerebral hemisphere levels inhibitory control on the mechanisms of the colliculus of the opposite side of the brain.

The deficiencies of optic nystagmus which occur as a result of the elimination of one eye or of one superior colliculus are almost entirely confined to deficiencies in the pursuit phase of the response. It has often been observed that under conditions such that the pursuit movements are very infrequent and irregular or indeed abolished altogether there may occur exaggeration of the saccadic phases of the nystagmus, both in the execution of a series of rapid jerks during the period of stimulation and in the occurrence of saccadic after-move-

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ments. These observations suggest that the mechanisms controlling the saccadic phase of the nystagmus are distinct from the collicular centers controlling the pursuit movements. The normal relations between the saccadic mechanisms and the pursuit mechanisms act so as to inhibit the saccadic release, and thereby to slow down the frequency of nystagmus, to accelerate extinction, and to prevent persistence of after-nystagmus. The cerebral cortex performs a similar inhibitory function in optic nystagmus, presumably by its relation to the saccadic mechanisms.

The systematization of all facts bearing upon the optic nystagmus of the guinea pig and its neural determination is none too easy. A possible general scheme of some of the main neural relations involved is shown in Fig. 5. In this drawing, solid lines indicate excitatory

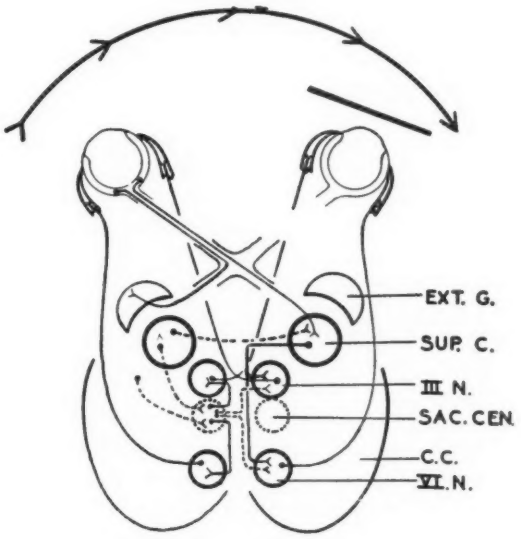

FIG. 5. Diagrammatic scheme representing some aspects of the neural determination of optic nystagmus in the guinea pig

Solid lines indicate excitatory relations, dotted lines, inhibitory relations. The dotted circles represent postulated centers which determine the saccadic phase. The right eye is covered, and the stimulus field is moving toward the right.

relations, dotted, inhibitory relations, between centers of the nervous system involved in optic nystagmus. A center, shown by dotted circles, for the determination of the saccadic phase is postulated. The relations indicated apply to conditions in which the right eye is

covered and the animal is stimulated by movement of the visual environment to the right, which will produce pursuit to the right and saccadic reactions to the left. For the purposes of this general discussion, we have chosen to apply the data to eye nystagmus rather than to head nystagmus as recorded. The two are closely integrated in the guinea pig, although eye nystagmus has somewhat greater frequency (Smith, **8**).

With movement of the visual environment to the right, the pursuit phase to the right is determined by stimulation of the left eye. The next level in the mediation of pursuit to the right is the right superior colliculus. Anatomically, this fact could be predicted from the knowledge that each retina in rodents, as well as in higher animals, is projected on the superior colliculus almost exclusively by crossed fibers going to the contralateral optic tectum. The functional proof of the fact is indicated by the experimental observation that (incomplete) removal of the right optic tectum almost completely abolishes pursuit responses to the right. It is presumed that the right colliculus has direct ipsilateral relations with the motor nuclei of the III and VI nerves, from which arise the final common paths to the lateral recti determining horizontal pursuit to the right. Since the opposite lateral muscles are reciprocally innervated, it must be presumed that the motor centers controlling the muscles giving pursuit to the right also control the reciprocal innervation of the antagonistic muscles.

Imposed upon the centers of optic pursuit are neural connections which, in the normal animal, inhibit the activity of these centers. These inhibitory paths are indicated by the dotted lines in the figure. Evidence for the inhibitory relations rests on observations that with removal of one colliculus or of one cerebral hemisphere, responses toward the side opposite the lesion are increased in frequency. Accordingly the colliculus and the cerebral cortex of the left side may be interpreted as having inhibitory relations with either the centers of pursuit or of the saccadic reactions of responses to the right. Two interpretations of these inhibitory relations are possible. The colliculus and cortex of the left side may inhibit directly, through their balanced relations with the colliculus or eye movement centers on the right side of the brain, the pursuit reactions to the right. Or, the colliculus and cortex of the left side may level a normal inhibitory control on the saccadic centers of reactions to the right, which control the frequency of nystagmus according to the rate at which they discharge in the course of pursuit responses. It is this general theory that is presented in Fig. 5. It is further assumed that the saccadic center of reactions to the right is related directly to the motor centers of pursuit responses in this same direction.

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The general diagrammatic relations given here provide only a superficial analysis of a very important problem about the determination of these nystagmic responses. Why is it that one eye alone determines nystagmic pursuit movements in a given direction, although both eyes are normally stimulated? A very simple answer which comes to mind is that the superior colliculus on one side, receiving fibers from only one eye, acts as the efferent outflow for responses in one direction. This statement, however, really accounts for nothing, for both colliculi must be activated during rotation, inasmuch as both retinæ are stimulated. Further, certain results which have been reported by Blohmke (1) indicate that lateral movements of the eyes cannot be produced by stimulation of the roof nuclei of the superior colliculi in rabbits, but are elicited by stimulation of the deeper structures of the midbrain, a fact that would seem to raise doubts about the direct efferent functions of the superior colliculus. Further consideration of this problem leads to the belief that the processes determining pursuit of the eyes and head to movement of the visual environment are much more complicated than is indicated, for example, by the diagram discussed above. The optic nystagmus of animals produced by compound moving visual contours is dependent upon summation effects of changes in contour of the patterns moving across the field. This is known from the fact that the frequency of the nystagmus is a function of the number of visual contours passing across the visual field per second. It may be that the summation processes basic to the nystagmic pursuit, as determined by the colliculus, are developed and maintained only by a certain order of stimulation of cells within each colliculus. Thus, visual movement in a given direction would give rise in one colliculus to an order of stimulation effective in releasing pursuit movements, whereas the mirror image of that order in the other colliculus would be required to be effective. At present, some such scheme is the nearest we can come to the physiological explanation of the peculiar role played by each eye and each colliculus in determining nystagmic pursuit in a single direction of movement.

2. *The central neural mechanisms of movement vision in animals.*

Normally the guinea pig does not display pursuit movements of the eyes or nystagmic movements of the head or eyes to movement of single objects or isolated patterned contours in the field of vision. In this respect, rodents differ from cats and other higher mammals which do respond to such stimuli. Now, movement vision associated with isolated objects is abolished in the cat by destruction of the visual areas of the cortex, leaving as a residual type of movement discrimination reactions associated with movement of compound

visual patterns. This type of vision is the type normally found to exist in the guinea pig, and the type of movement vision apparently dependent on the collicular centers. The arrangement of the neural centers of each colliculus in the guinea pig seems to be such that each colliculus determines the animal's ability to distinguish, in terms of differential reactions, movement of stimuli in only one direction.

In mammals which possess the dual type of movement vision, as cat, monkey, and man, it remains to show to what extent there is a division of neural functions for responses to different directions of movement in the horizontal plane. Unpublished evidence indicates that in the cat with both occipital lobes removed, there is a separation of the subcortical neural mechanisms much like that which exists normally in the guinea pig. That is, in these operated animals, covering on one eye largely abolishes pursuit reactions in one direction of movement, but leaves intact pursuit in the other direction.

3. *The significance of the present results to the general problems of the neural bases of visual capacities.*

Experimental studies of the functions of the superior colliculi in relation to visual capacities have not indicated specifically what the basic significance of these bodies may be. Freeman and Papez (**2**) and Ghiselli (**4**) have reported that injuries to the superior colliculi in the rat do not abolish a brightness habit previously established. Layman (**5**) and Ghiselli (**3**) have observed that pattern vision for visual forms or striated patterns is not interfered with by different degrees of destruction of the two superior colliculi. These results, which have been considered along with other work on the visual areas of the cortex, have been taken to indicate that the striate areas of the cortex and the superior colliculi normally function equivalently in brightness discrimination, although the two levels of neural adjustment may not operate in the same way in pattern vision.

The present results indicate that the optic cortex and the superior colliculi function quite differently in the mediation of pattern vision and movement vision. This is probably true in the cat and other mammals which possess focal vision, as well as in the guinea pig. The present data combined with previous studies indicate that the cerebral mechanisms of vision provide the basis for focal pattern vision, while the superior colliculi, along with other primary optic centers, normally provide the basis for pattern vision of moving compound contours and the visual acuity for the perception of these patterns, as well as brightness discrimination and flicker vision, at both high and low levels of illumination.

A considerable number of experiments have been directed toward the question of the relation between the cortex and subcortical optic

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centers in regard to the maintenance of visual capacities. A specific problem involved is that of the loss of learned visual habits after extirpation of the visual areas and the reacquisition of these habits with postoperative training. In the light of the present results it seems logical to believe that the dynamic balances of function existing between different levels of the visual system may be of significance in accounting for the effects of operative lesions of the optic cortex and other visual structures on the retention of acquired habits, for it seems clear that the mechanisms which determine inhibition and release of visual pursuit reactions must also play some rôle in the definition of capacities associated with these reactions.

(Manuscript received June 28, 1943)

References

1. Blohmke, A. Ueber den durch elektrische Reizung des Hirstammes auslösbaren Nystagmus beim Kaninchen. I. Bestimmung des Auslöszentrums. *Z. Hals-, Nasen-, u. Ohrenhk.*, 1929, **23**, 213–241.
2. Freeman, G. L., & Papez, J. W. The effect of subcortical lesions in the visual discrimination of rats. *J. comp. Psychol.*, 1930, **11**, 185–192.
3. Ghiselli, E. E. The superior colliculus in vision. *J. comp. Neur.*, 1937, **67**, 451–467.
4. Ghiselli, E. E. The relationship between the superior colliculus and the striate area in brightness discrimination. *J. genet. Psychol.*, 1938, **52**, 151–157.
5. Layman, J. D. Functions of the superior colliculi in vision. *J. genet. Psychol.*, 1936, **49**, 33–47.
6. Mowrer, O. H. A comparison of the reaction mechanisms mediating optokinetic nystagmus in human beings and pigeons. *Psychol. Monogr.*, 1936, **47**, 294–305.
7. Smith, K. U. The effect of partial and complete decortication upon the extinction of optic nystagmus. *J. genet. Psychol.*, 1941, **25**, 3–18.
8. Smith, K. U. Experiments on the neural basis of movement vision. *J. exp. Psychol.*, 1941, **28**, 199–215.
9. Smith, K. U., & Warkentin, J. The central neural organization of optic functions related to minimum visible acuity. *J. genet. Psychol.*, 1939, **55**, 177–195.

MEDIATED GENERALIZATION AND THE INTERPRETATION OF VERBAL BEHAVIOR

IV. Experimental Study of the Development of Inter-Linguistic Synonym Gradients [1]

BY JOHN P. FOLEY, JR., AND MARY A. MATHEWS

The George Washington University

Introduction

In the initial paper of the present series (1), a theoretical account of the conditioned response phenomenon of mediated generalization was presented and it was suggested that various aspects of verbal behavior might be understood in terms of mediated as well as non-mediated generalization. Subsequent papers reported evidence of generalization (*a*) along more than one homophone gradient from a given stimulus word (3), (*b*) along a synonym gradient from the stimulus word (3), (*c*) along a synonym gradient two degrees of transformation removed from the original stimulus word (3), and (*d*) along an antonym gradient from the stimulus word (2). The positive results indicating generalization along all of these dimensions may be interpreted as, to this extent, confirming the previous theoretical analysis (1).

If we accept the fact of mediated generalization along, let us say, synonym gradients, the question may next be raised as to the *origin* of such synonym gradients. More specifically, can we control the experimental stimulus-response conditions in such a way that synonym generalization will or will not take place? And in what manner would such mechanisms operate in the common verbal behavior of every-day life? It is with these questions that the present study is concerned.

In other words, the present study represents an attempt to investigate experimentally the *origin* and *development* of synonym generalization under normal every-day stimulational conditions, such as are afforded by classwork in a foreign language. The experimental design thus required two groups, originally matched with respect to the recall of a list of English words presented immediately after

[1] The present paper represents part of a research project being conducted by Dr. C. N. Cofer and the senior author under a grant-in-aid from the American Association for the Advancement of Science. The writers are indebted to Dr. Cofer for a critical reading of a preliminary copy of the manuscript.

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several reinforcements with lists of their Spanish equivalents. One (Experimental) group then received several weeks of the usual instruction in Spanish; the other (Control) group did not. Then both groups were again given reinforcements with the same Spanish lists, after which the same list of English equivalents was presented and its recall tested.

METHOD

1. *Materials.*—Spanish words were selected for use in the present study because of the possibility of getting Spanish words, included in the vocabularies of the beginning lessons, which did not bear a resemblance to English words or to words in other languages with which a subject might be familiar.[2] The 10 words selected were taken from the vocabularies presented in the first 10 lessons of the textbook [3] used in the elementary Spanish classes. These words are presented in Table I, as is the Test List of 10 English words, each being the prescribed equivalent of one of the Spanish words. In each case, care was taken to select short Spanish words which least resembled, homographically or semantically, any English word, and every effort was made to minimize other complicating semantic relationships.[4]

In addition to the above two lists, two other 'buffer' or practice lists were utilized, to be used at the beginning of the initial and final testing, respectively. As indicated in Table I, Buffer

TABLE I

LISTS OF WORDS USED IN THE EXPERIMENT

Buffer List A	Buffer List B	Spanish Reinforcement List			
		First Presentation	Second Presentation	Third Presentation	English Test List
eleven	edith	(3) hijo	(2) cosa	(4) ciudad	(1) street
six	bernard	(4) ciudad	(7) pared	(9) reloj	(2) thing
forty	louise	(7) pared	(8) zapato	(5) cuaderno	(3) son
three	vivian	(2) cosa	(1) calle	(10) tiza	(4) city
sixteen	joseph	(8) zapato	(3) hijo	(7) pared	(5) notebook
nine	dorothy	(9) reloj	(10) tiza	(6) cena	(6) supper
twelve	henry	(10) tiza	(9) reloj	(3) hijo	(7) wall
five	calvin	(6) cena	(5) cuaderno	(1) calle	(8) shoe
		(5) cuaderno	(4) ciudad	(8) zapato	(9) watch
		(1) calle	(6) cena	(2) cosa	(10) chalk

List A consisted of eight numbers (spelled out) and Buffer List B was composed of eight Christian names. These lists were similar to those employed in previous studies of this series (2, 3), the selection of numbers and names being dictated by the desire to minimize the possibility of generalization effects from these sources.

2. *Procedure.*—The Buffer Lists, the three presentations of the Spanish Reinforcement List, and the English Test List were the same for all 80 *Ss*. The same intra-serial order (that of Table I) was used for every *S* in the case of all lists. Retention was measured by the method of retained members for the Buffer and English Test Lists, the *Ss* being told that they would not be asked to

[2] German words, for example, were excluded because of their frequent resemblance to Yiddish words.

[3] Turk, L. H. *Introduction to Spanish.* Boston: Heath, 1942. Pp. 331.

[4] The writers recognize the possible existence of generalization gradients arising from the instructions as well as the possible existence of intra-serial 'circular' gradients, such as *city-wall, city-street, chalk-notebook.* Since the materials and methodology were identical for the experimental and control groups, however, such factors would not operate differentially in the case of the two groups.

remember the Spanish Reinforcement Lists. It will be noted that the three presentations of the Reinforcement List contain the same words but in a different order, the same intra-serial order and sequence of lists being followed for every *S* in both Experimental and Control groups. Thus the positions throughout the reinforcement presentations of all Spanish words having a semantic relationship to a given English word in the Test List were the same for all *S*s. The serial orders of word presentation are shown in Table I, reading from top to bottom, and the relationships of semantic equivalence between Reinforcement and Test Lists are indicated by the numbers in parentheses.

The first testing was done between September 30 and October 22, 1942, before any of the *S*s had had instruction in Spanish. Both Experimental and Control groups were run simultaneously. Classes had been in session for only a short time, and none of the *S*s at that time knew the meaning of any of the Spanish words; in fact most of the *S*s did not know that they were Spanish words. The second testing was carried out between November 16 and December 16, 1942, both groups again being run simultaneously, so that the amount of time since initial testing was the same for both groups. By the second testing, the Experimental group had completed the first 10 Spanish lessons (*cf.* Materials), so that they had presumably formed many or all of the Spanish-English associations employed in the present experiment. The Control group had not been instructed in Spanish during this period. According to the hypothesis previously advanced (1), the experimental repetition (reinforcement) of the Spanish words should increase the reaction potentials of their English equivalents to a greater extent in the Experimental (Spanish-instructed) than in the Control (non-Spanish-instructed) group; if this should occur, one should expect the English Test List to be better retained by the Experimental than by the Control group.

Each *S* was tested individually in an inside, windowless room, having a low noise level. The lists were typed on white paper and presented one word at a time by means of the Gerbrands memory drum (5, No. Ml-4). By using a multiple-exposure shield, previously described (4), no change of paper was necessary for the exposure of the five lists. The drum was set at the one and one-half sec. exposure speed for the presentation of all words. Each experimental session required approximately 10 min. for each *S*.

The regular procedure was as follows. After the *S* had been comfortably seated at a table containing only the memory drum, the following specific *instructions* were given by *E*: "Watch this opening (indicating it) in which a series of words will be exposed one at a time. As each word is exposed, say it aloud and think of its meaning. When all the words have been exposed, you will be asked to put down on paper as many of the words in this series as you can remember. Are there any questions?" Buffer List A was then presented, after which *S* was given a slip of paper and a pencil with the instructions: "Now, put down as many words in this list as you can remember; their order is not important." The slip of paper containing the recalled words was taken up by *E*, who then gave the following instructions before presenting the Reinforcement Lists: "Now *this* time you will be given a list of words in a foreign language. As each word appears, say it aloud *as best you can* and try to think of its probable meaning. You will *not* be called upon to remember this list, although you should make an effort to think of the meaning of each word as you pronounce it aloud." No other comments were made during the presentation of the three Reinforcement Lists, other than to repeat the above instructions before each presentation. Before the presentation of the English Test List, *E* said: "Now *this* time you will be given a list of English words. As each word appears, say it aloud and think of its meaning. When all the words have been exposed, you will be asked to put down as many of the words in *this list* as you can remember." The procedure followed in the second testing was identical to that of the first testing except that Buffer List B replaced Buffer List A.

Following *S*'s recall of the English Test List, he was asked the following questions in order: 1. "Do you have any comments?" 2. "Did you make use of any aids or other devices to help your recall? What devices?" 3. "Did you notice any relationship between words on any of the different lists? What relationships?" These questions were repeated at the conclusion of the second testing, after which a fourth question was asked: "Did you notice any specific relationship between any of the foreign words and any of the English words? What relationship?"

3. *Scoring.*—In the case of the Buffer Lists and the English Test List, the score was computed in terms of number of words correctly recalled, as in the method of retained members. The order in which the words were recalled was not considered. All legible words were scored, and slight mistakes in spelling did not count as errors so long as it was clearly evident that the correct word and not some other word (especially the homophone) was intended.

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4. *Subjects.*—Eighty *Ss* were used in the experiment, 17 male and 63 female. They were obtained from Spanish and Psychology classes and were entirely naïve with respect to the purpose of the experiment. As previously described, the *Ss* were divided into Experimental and Control groups of 40 *Ss* each, equated on the basis of scores on the first administration of the English Test

TABLE II

ANALYSIS OF PERFORMANCE OF EXPERIMENTAL AND CONTROL GROUPS ON BUFFER LISTS A AND B

Measures	Buffer List A		Buffer List B	
	Experimental Group	Control Group	Experimental Group	Control Group
N	40	40	40	40
Total Correct	221	225	235	235
Total Incorrect	22	22	1	4
Range Correct	3–8	4–7	4–7	3–8
Mean Correct	5.53	5.63	5.88	5.88
S.D. Correct	1.10	.94	.84	1.00
Median Correct	5.57	5.74	5.91	5.88
Q Correct	.74	.71	.64	.67

List. Thus from the data presented in Table III it will be noted that the two groups make mean scores of 6.25 and 6.38, respectively, whereas the respective median values are 6.56 and 6.37. The reliability of these differences will be discussed in the following section. Although no attempt was specifically made to match the two groups for Buffer List score, inspection of Table II will reveal that the groups are well equated in mean and median scores on both Buffer List A and Buffer List B; these data lend additional confirmation to the statement that the two groups were well equated in 'learning ability.' The groups were also approximately equated as to age, sex ratio, and number of years in college.

RESULTS

The major results of the experiment, in terms of the number of words on the English Test List correctly and incorrectly recalled by both groups on the initial and final testing, are presented in Table III. The reliabilities of the differences between Experimental and Control groups on the first and second testings are reported in Table IV.[5] It will be noted that computations of central tendency, variability, and reliability are reported in terms of both mean and median measures.

On the first testing, the differences between the Experimental and Control groups are small and statistically insignificant. Thus a

[5] Since normality of distribution could not be assumed, σ_{Mdn} was computed throughout by the following formula: $\sigma_{Mdn} = \frac{i\sqrt{N}}{2F}$.

TABLE III

ANALYSIS OF PERFORMANCE OF EXPERIMENTAL AND CONTROL GROUPS ON FIRST AND SECOND TESTINGS WITH ENGLISH TEST LIST

Measures	First Testing			Second Testing		
	Experimental Group (E)	Control Group (C)	Difference (E)–(C)	Experimental Group (E)	Control Group (C)	Difference (E)–(C)
N	40	40		40	40	
Total Correct	250	255	−5	308	273	35
Total Incorrect	17	14	3	3	14	−11
Range Correct	4–8	3–9		5–10	5–10	
Mean Correct	6.25	6.38	−.13	7.70	6.83	.88
S.D. Correct	1.18	1.30		1.29	1.28	
Median Correct	6.56	6.37	.19	7.70	6.63	1.08
Q Correct	.82	.76		.97	1.01	

TABLE IV

RELIABILITY OF DIFFERENCES BETWEEN SCORES OF EXPERIMENTAL AND CONTROL GROUPS ON FIRST AND SECOND TESTINGS, RESPECTIVELY

Analysis in terms of Mean			Analysis in terms of Median		
Measures	First Testing	Second Testing	Measures	First Testing	Second Testing
σ_{M_E}	.19	.21	σ_{Mdn_E}	.19	.32
σ_{M_C}	.21	.21	σ_{Mdn_C}	.21	.40
$\sigma_{M_E-M_C}$	.28	.29	$\sigma_{Mdn_E-Mdn_C}$	.28	.51
M_E-M_C	−.13	.88	Mdn_E-Mdn_C	.19	1.08
Significance Ratio	−.45	3.01	Significance Ratio	.68	2.12
Probability Value	.6718	.9987	Probability Value	.7527	.9832

mean of 6.25 words was recalled by the Experimental group as compared with a mean of 6.38 words by the Control group. The reliability of this difference is indicated by a significance ratio of −0.45, with a probability of .6718 that such a difference would not have arisen as a sampling error from a true difference of zero. Similarly, the median value of 6.56 words recalled by the Experimental group is .19 words larger than that for the Control group; the sigma of the difference is .28, with a significance ratio of 0.68 and probability-

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value of .7527. Thus, no significant differences exist with respect to the mean or median number of words recalled by the two groups on the first testing. The fact that the small differences are in opposite directions in the case of mean and median measures also indicates that the groups were well equated in performance on the initial testing.

On the second testing, however, prior to which the Experimental group had received class instruction in Spanish, the differences are large and statistically significant. The mean numbers of words recalled by the Experimental and Control groups are 7.70 and 6.83, respectively, the difference of .88 words yielding a critical ratio of 3.01 and probability-value of .9987. In terms of the median, the difference is also very striking, the significance ratio being 2.12 with a probability-value of .9832. The probability that such a difference might have arisen from chance factors is thus very small.

Since the differences between Experimental and Control groups were small and insignificant on the first testing, but large and significant on the second testing, and since Spanish instruction of the Experimental group was the only experimental variable, the results would seem to indicate the operation of generalization gradients established in the Experimental group during the Spanish instruction. It is interesting to note that the mean for the Experimental group on Buffer List B, following Spanish instruction, is identical with that of the Control group, and that their medians are also approximately the same (*cf.* Table II). It is thus apparent that the Spanish instruction did not generalize to the Christian names in Buffer List B, a result to be expected in terms of the theory of mediated generalization under consideration.

An additional check on the results is afforded by comparing the gross number of *Ss* in the Experimental and Control groups who showed an increase, no change, or a decrease in number of correct English words recalled from the first to the second testing. These data are reported in Table V. It will be noted that 80 percent of the

TABLE V

TOTAL FREQUENCY OF SUBJECTS IN EXPERIMENTAL AND CONTROL GROUPS SHOWING INCREASE, NO CHANGE, OR DECREASE IN NUMBER OF CORRECT WORDS RECALLED FROM FIRST TO SECOND TESTING

Nature of Change	Experimental Group		Control Group	
	Number of Subjects	Percentage of Subjects	Number of Subjects	Percentage of Subjects
Increase	32	80.0	17	42.5
No change	4	10.0	13	32.5
Decrease	4	10.0	10	25.0

Experimental group and only 42.5 percent of the Control group showed an increase in score on the second testing; 10 percent of the Experimental group showed no change in score, as compared with 32.5 percent of the Control group; and only 10 percent of the Experimental group showed a decrease in score, whereas 25 percent of the Control group showed a decrement. These results are corroborated by the range in magnitude of the change in score from first to second testing, the range being from 4 to −1 in the Experimental group, and from 3 to −2 in the Control group.

Perhaps the clearest indication of mediated generalization effects, however, is found in a direct statistical comparison of the changes from first to second testing in the case of the Experimental and Control groups. The measures of central tendency and variability of these changes [6] will be found in Table VI, and the reliability of inter-

TABLE VI

CENTRAL TENDENCY AND VARIABILITY OF INCREASES IN SCORE OF EXPERIMENTAL AND CONTROL GROUPS FROM FIRST TO SECOND TESTING

Measures	Experimental Group	Control Group
Mean Increase	1.53	.45
S.D. of Increases	1.38	1.45
Median Increase	1.50	.27
Q of Increases	.87	1.07

group differences in such changes is indicated by the data presented in Table VII. From these tables it is seen that the Experimental group showed a mean increase of 1.53 and median increase of 1.50

TABLE VII

RELIABILITIES OF THE DIFFERENCES BETWEEN EXPERIMENTAL AND CONTROL GROUPS IN MEAN AND MEDIAN INCREASES IN SCORE FROM FIRST TO SECOND TESTING

Analysis in Terms of Mean		Analysis in Terms of Median	
σ_{M_E}	.22	σ_{Mdn_E}	.28
σ_{M_C}	.23	σ_{Mdn_C}	.24
$\sigma_{M_E-M_C}$	.32	$\sigma_{Mdn_E-Mdn_C}$	.37
M_E-M_C	1.08	Mdn_E-Mdn_C	1.23
Significance Ratio	3.36	Significance Ratio	3.35
Probability Value	.9996	Probability Value	.9996

words correctly recalled from the first to the second testing. In marked contrast, the corresponding increases for the Control group were only 0.45 and 0.27 words. The increases in Control mean and

[6] Since there were a few negative values, or decreases from the first to second testings, the mean, median, S.D. and Q were computed algebraically.

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median may be attributed primarily to practice effects, and may thus serve as a base for evaluating the improvement displayed by the Experimental group. The difference of 1.08 between the Experimental and Control groups in mean change from first to second testing yields a significance ratio of 3.36 and probability-value of .9996. An equally reliable difference is obtained in the case of the median. The chances that such an inter-group difference could have arisen as a sampling error from a true difference of zero are thus extremely small, so that the operation of generalization gradients established during the Spanish instruction of the Experimental group is clearly indicated.

The number of *correct recalls* of each presentation word in Buffer Lists A and B as well as in the first and second testings with the English Test List have been tabulated. The relative frequency of recall of a given presentation word did not differ markedly from the Experimental to the Control group, and intra-serial primacy and recency effects were clearly apparent in the case of all lists. Differences in the preëxperimental reaction potentials of all words, as well as differences in serial position, make further analysis of this matter unwarranted.

An analysis of the individual *incorrect recalls* in each of the two groups in most cases reveals generalization effects theoretically similar to those reported above as producing correct recalls. With one exception (*fix*, probably intended as *five* or *six*), all of the 44 incorrect recalls of Buffer List A in both groups (*cf.* Tables I and II) were incorrect numbers, the incorrectly recalled number often being a verbal compound of the correct presentation number, as in the case of the relationships *three—thirteen*, *five—fifteen*, *nine—nineteen*, *forty—forty-three*, *forty—forty-five;* a quantitative treatment of these and other semantic relationships is impossible owing to the nature of the stimulus words. The total of five incorrect recalls of Buffer List B were all Christian names: *George*, *Harry*, *Helen*, *Lillian*, *William*.

Of greater interest are the incorrect recalls of the English Test List, for here the operation of generalization gradients is strongly suggested. A complete discussion of the incorrect recalls made by both groups on the two testings combined would seem to be justified. The most common error was the incorrect recall of *walk*, which accounts for 25 of the total of 48 errors made by both groups on both testings. The related recall of *sidewalk* occurred two times in the combined tabulation of total errors. Both *walk* and *sidewalk* bear a quasi-synonym relationship to *street* in the Test List, and the single incorrect recall of *gutter* is in the same general category; *walk* also bears a quasi-homophonic relationship to the presentation word *chalk*. From the presentation words *notebook* and *chalk*, generaliza-

tion seems to have occurred to words in an 'educational category,' as evidenced by two incorrect recalls of *school*, of *study*, and of *pencil*, and a single incorrect recall of *pen* and of *paper*. The single incorrect recall of *pocketbook* is partially identical to the presentation word *notebook*. The single incorrect recall of *boy* and of *brother* would seem explicable in terms of their relationship to the presentation word *son*, whose homophone, *sun*, also occurred once as an incorrect recall. The two incorrect recalls of *dinner* bear a close semantic relationship to the presentation word *supper*, as does the single recall of *food*. The incorrect recall of *repair* may be attributed to its relationship to *shoe* in the Test List, as may the recall of *hose* by a single female *S*. There remain only three of the total of 48 incorrect recalls of the English Test List unaccounted for in the above discussion; in these cases (*one*, *thick*, *shells*) the relationship to a presentation word is either ambiguous or obscure.

Finally, let us consider the *S*s' verbal reports. Reference to the Procedure will reveal that each *S* was asked three questions at the conclusion of the first testing and that the same three questions in addition to a fourth were asked at the end of the second testing. These questions were primarily directed towards discovering whether or not the *S* had perceived the semantic relationship between the Spanish Reinforcement Lists and the English Test List. None of the Control group reported the relationship on the first testing; on the second testing three Control *S*s correctly reported a single instance of a Spanish word in the Reinforcement Lists meaning the same as an English word in the Test List. Of these three *S*s, two were not very certain of the relationship in meaning, and the third reported having come across the relationship in reading in English literature. In addition to these three *S*s, two other members of the Control group reported a general suspicion of such a relationship, although they were unable to cite one or more correct examples. In the Experimental group, four *S*s reported a single case of such a relationship on the first testing; one of these *S*s stated that his perception was based upon his knowledge of Latin; another reported that his example "may be a guess." From all indications, most of the *S*s did not even identify the Reinforcement List as Spanish words at the time of the first testing. On the second testing, two *S*s in the Experimental group failed completely to report the relationship, even after being asked all four questions; 11 *S*s reported the relationship in a few of the words; and 27 reported the generalized relationship. Of this latter group, four specifically stated that they did not perceive the relationship at the time, *i.e.*, they were able to report it only after being questioned; on the other hand, three *S*s reported a definite attempt to utilize the Spanish-English associations as an aid in recall.

Numerous other comments were made by the *S*s of both groups in answering the questions. Many reported that Buffer List A contained only numbers, that Buffer List B contained only Christian names, that the three Spanish Reinforcement Lists contained the same words but in different orders, and that the lists employed on the two testings were the same except for the Buffer List. Various mnemonic devices were also reported, and there was frequent speculation concerning the nature of the experiment, as well as postulation of incorrect relationships. A detailed treatment of these comments would seem unwarranted.

Theoretical Analysis

Let us now consider the theoretical analysis of the present experiment [7] in terms of the concepts of classical conditioning and of mediated generalization. The theoretical mechanisms involved are diagrammatically presented in Fig. 1, to which reference should be made in connection with the discussion which follows. The procedure employed in the initial testing was the same for both Experimental and Control groups, and can be disregarded in the present theoretical analysis.[8]

Following the initial testing, the Experimental group received Spanish instruction, whereas the Control group did not. Theoretically, it is assumed that during this period of Spanish instruction, the Experimental group acquires the Spanish-English associations,[9] so that the Spanish words come to serve as conditioned stimuli for their appropriate English equivalents. This is brought about through the visual and auditory presentation of the English word, e.g., *supper* (*UCS*), followed by the *S*'s vocalization and/or subvocalization of the response word *supper*; when this occurs simultaneously with the visual and auditory presentation of the spanish word *cena*, the latter becomes a conditioned stimulus (CS_x) for the vocal response *supper* (*R*) [10] and its subvocalization or implicit, fractional

[7] Although no theoretical analysis was reported in previous experimental papers of this series, the present analysis can be applied, with modifications, to the previously reported experimental demonstration of generalization along synonym (3) and antonym (2) gradients.

[8] As previously indicated in the section on Procedure, the initial testing of both Experimental and Control groups was carried out (*a*) to determine the amount of recall of the English words on the part of both groups prior to Spanish instruction of the Experimental group, and (*b*) to insure that both groups were approximately equated in this respect.

[9] The writers recognize that only certain of these associations were formed, although this fact does not alter the experimental design or present theoretical analysis.

[10] This would be the simplest case. It is also conceivable that some other response, such as the implicit movement of the finger or arm or a movement of the stomach or other part of the digestive tract, might also occur in this situation and might become conditioned to both *cena* and *supper*. The rôle of such complicating factors has been advisedly omitted from the present discussion, although its inclusion would not essentially alter the nature of the theoretical analysis which follows.

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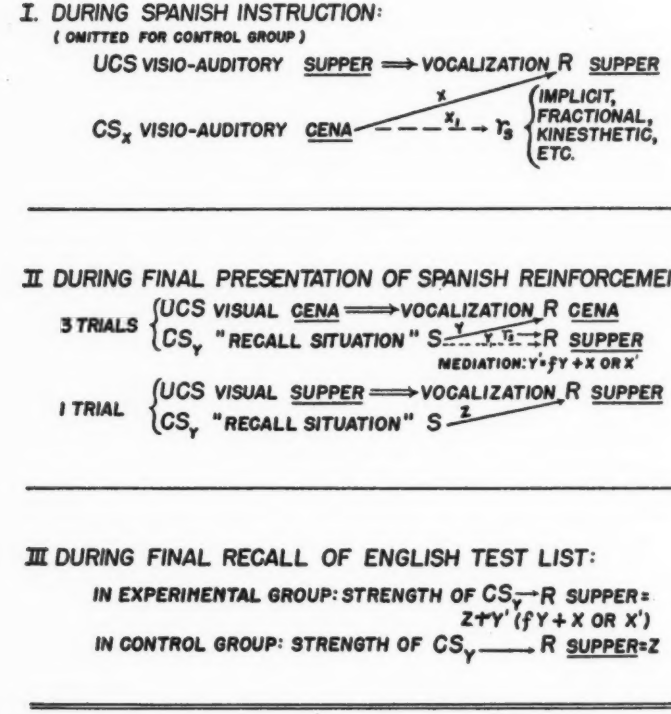
I. DURING SPANISH INSTRUCTION:
(OMITTED FOR CONTROL GROUP)
UCS VISIO-AUDITORY SUPPER ⟹ VOCALIZATION R SUPPER
CS$_x$ VISIO-AUDITORY CENA
x
x$_1$ → r$_s$
IMPLICIT, FRACTIONAL, KINESTHETIC, ETC.
II DURING FINAL PRESENTATION OF SPANISH REINFORCEMENT LISTS:
3 TRIALS
UCS VISUAL CENA ⟹ VOCALIZATION R CENA
CS$_y$ "RECALL SITUATION" S
y
x r$_s$
R SUPPER
MEDIATION: Y'·fY + X OR X'
1 TRIAL
UCS VISUAL SUPPER ⟹ VOCALIZATION R SUPPER
CS$_y$ "RECALL SITUATION" S
z
III DURING FINAL RECALL OF ENGLISH TEST LIST:
IN EXPERIMENTAL GROUP: STRENGTH OF CS$_y$ → R SUPPER = Z+Y' (fY + X OR X')
IN CONTROL GROUP: STRENGTH OF CS$_y$ → R SUPPER = Z

FIG. 1. Theoretical schema illustrating the rôle of mediated generalization in the development of inter-linguistic synonym gradients

kinesthetic responses with their attendant stimulus function (r_s). In Fig. 1, the strength of the conditioned vocalized R to *cena* (CS_x) is denoted by x, and that of the attendant implicit, fractional kinesthetic responses is denoted by x'. These reaction potentials would not, of course, exist in the case of the Control group.

In the final test situation, the three presentations of the list of Spanish words constitute a conditioning situation in which the visual presentation of the word *cena* (or other Spanish word) is followed (through instructions) by the S's vocalized response *cena*, the latter becoming conditioned, through direct reinforcement, to some unspecified 'recall stimulus' (CS_y), such as the memory drum, experimental room, or some other aspect of the complex stimulus situation. In Fig. 1, the strength of this reaction potential is denoted by y. Now, the vocalized response *cena* is attended by subvocal and implicit fractional kinesthetic responses with their resulting stimulus func-

tions (r_s), and as noted above, the latter have been previously conditioned to the response *supper*. Thus in the Experimental group, indirect or 'mediated' generalization will occur from the 'recall stimulus' (CS_y) to the response *supper*, the strength of which mediated association is denoted in Fig. 1 by y'. This indirect or mediated generalization from CS_y to the response *supper*, via *cena*, will thus strengthen the reaction potential of that response. No such mediation will exist in the case of the Control group.

Finally, in the single presentation of the English Test List, the visual presentation of the English word *supper* (*UCS*) is followed by vocalization (*R*) of that word (*cf.* Procedure), the vocalized response becoming conditioned (to a greater or lesser degree) to the simultaneously present 'recall' or 'memory drum situation' stimulus (CS_y), the strength of which association is denoted by z in Fig. 1. This latter reinforcement of the behavior segment $CS_y \rightarrow R$ *supper* is present in both the Experimental and Control groups, so that the magnitude of z may be assumed to be common and equal for both groups. In the case of the Experimental group, however, z will theoretically be incremented by y' (*cf.* above),[11] the latter being a function of y plus x or x'. Since y' is not present in the case of the Control group, this incrementation will occur only in the case of the Experimental (Spanish-instructed) group, so that the $CS_y \rightarrow R$ *supper* association will theoretically be stronger in the case of the latter group.[12] Hence a reliably greater number of the English words should be recalled by the Experimental group.[13] The positive results of the present experiment thus conform to predictions made on the basis of the present theoretical analysis.[14] These results are all the more significant when it is realized that many of the *S*s in the Ex-

[11] It may be assumed that incrementation of z will occur by algebraic summation with y' (the magnitude of the reaction potential derived indirectly via *cena*).

[12] Stated in other words, the reaction potential of the response *supper* is derived in the Control group solely from the experimental presentation of that word, whereas in the case of the Experimental group there is the additional incrementation indirectly through *cena*. Since the Experimental and Control groups were initially equated with respect to the P-list of English words, and since the methodologically differentiating factor was the additional reinforcement derived indirectly through the Spanish instruction, any difference between the two groups in subsequent performance may be attributed to the influence of indirect or mediated generalization via the Spanish-English associations.

[13] In the interests of simplification, the present theoretical analysis has omitted consideration of intra-serial associations resulting from the conditioning of a given verbal response to the vocalization or sub-vocalization of its predecessor. In so far as the presentations of the test list were the same for Experimental and Control groups, this factor can be disregarded in the present analysis.

[14] It is possible, of course, that part of the improvement shown by the Experimental group resulted from the direct reinforcement of the English words themselves in the Spanish classroom. The fact that the words in the English Test List were so well known, however, would seem to discount the importance of such a factor, as would some of the evidence contained in the verbal reports of certain *S*s.

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perimental group did not know the meaning of all the Spanish words, as indicated by their own verbal reports.[15]

Summary

This experiment was designed to study the origin and development of mediated generalization under normal every-day stimulational conditions, such as are afforded by classwork in a foreign language. Two groups of 40 *Ss* each were originally equated with respect to the recall of a list of English words presented immediately after three reinforcements with lists of their Spanish equivalents. One (Experimental) group then received several weeks of the usual instruction in Spanish; the other (Control) group did not. Both groups were then retested, being given reinforcements with the same Spanish lists after which the same list of English equivalents was presented and its recall tested. A significant difference was now found between the two groups, the higher recall score of the Experimental group being interpreted in terms of the operation of mediated generalization gradients established in that group during the Spanish instruction. The theoretical analysis of mediated generalization previously presented (1) is extended and applied to the present experiment.

(Manuscript received July 8, 1943)

References

1. Cofer, C. N., & Foley, J. P., Jr. Mediated generalization and the interpretation of verbal behavior: I. Prolegomena. *Psychol. Rev.*, 1942, **49**, 513–540.
2. Cofer, C. N., Janis, M. G., & Rowell, M. M. Mediated generalization and the interpretation of verbal behavior: III. Experimental study of antonym gradients. *J. exp. Psychol.*, 1943, **32**, 266–269.
3. Foley, J. P., Jr., & Cofer, C. N. Mediated generalization and the interpretation of verbal behavior: II. Experimental study of certain homophone and synonym gradients. *J. exp. Psychol.*, 1943, **32**, 168–175.
4. Foley, J. P., Jr., & Cofer, C. N. An inexpensive multiple-exposure extension for the simple memory drum. *J. exp. Psychol.*, 1942, **31**, 438–439.
5. Gerbrands, R. *Scientific instruments.* (Mimeographed)
6. Hull, C. L. The problem of stimulus equivalence in behavior theory. *Psychol. Rev.*, 1938, **45**, 271–299.
7. Hull, C. L. *Principles of behavior.* New York: Appleton-Century, 1943. Pp. 420.

[15] Larger differences between the two groups could have doubtless been obtained if the Experimental group had been *experimentally* instructed with respect to the meaning of the specific Spanish words employed. The present experiment was concerned, however, with the formation of mediated generalization gradients in the usual, every-day-life situation.

THE COURSE OF ACQUISITION OF A CONDITIONED RESPONSE OF THE OCCIPITAL ALPHA RHYTHM

BY CHARLES SHAGASS

McGill University

AND

E. PARKER JOHNSON[1]

It has been shown in several studies that the human occipital alpha rhythm may be modified by conditioning procedures (**2**, **6**, **7**, **8**, **9**, **10**, **14**, **16**). After being presented several times, together with the adequate stimulus (light), a previously inadequate stimulus will depress the alpha rhythm. The CR[2] is very labile but almost all the classical Pavlovian types of CR have been demonstrated with sound as the CS (**7**, **9**). The CS may also be a voluntary act such as pressing a button or clenching the fist (**8**, **14**).

Various methods of measuring the response have been employed at different times. The senior author used and evaluated three of these in an earlier study (**14**). These were: the *alpha index*; the *amplitude index*; and the '*activity-level index*' (AL index). The AL index, which takes into account both amplitude and incidence of the waves, was found most suitable of the three. It is simple in derivation $\left(\text{AL index} = \frac{\text{alpha index} \times \text{amplitude index}}{100}\right)$, and may be measured directly by means of the cumulative measuring device described in the previous report.

In the same study (**14**) the AL index was used to demonstrate that, after being paired with light a number of times, a voluntary clench of the fist would cause a significant drop in the level of alpha activity immediately succeeding it. During several unreinforced trials following the acquisition of this CR, the AL index returned to its pre-conditioning level. This recovery, when graphed, resembled the characteristic extinction curve usually obtained for other types of CR. Inasmuch as the CR was acquired under conditions of irregular massed reinforcement, the course of acquisition could not be traced.

[1] The writers wish to express their grateful appreciation for the advice and criticism of Dr. H. H. Jasper of the Montreal Neurological Institute and Dr. D. B. Lindsley of Brown University.

[2] The following abbreviations are used: conditioned response—CR; conditioned stimulus—CS; unconditioned response—UCR; unconditioned stimulus—UCS; 'activity-level index'—AL index.

The main purpose of the present study was to determine the course of acquisition of the same response. A voluntary fist-clench was again used as the CS, but reinforcement was intermittent. The development of the CR was observed in the unreinforced trials. The results make possible a further comparison of the properties of this conditioned electrical response of the cortex with those of conventional peripheral responses.

In previous experiments (**8, 14**), the occurrence of anticipatory responses suggested that the S's conscious 'expectation' of the light stimulus may operate in the formation of the CR. An attempt was made here to investigate the role of this factor.

Technique

Apparatus.—A standard amplifier and ink-writing oscillograph were used to record the EEG and the muscle potentials produced by the fist-clench. Paper speed was 1.5 cm. per sec. The light stimulus was a 3-volt flashlight bulb, placed 24 in. in front of the *S*'s eyes, and controlled from outside the dark, electrically-shielded room in which the *S* lay.

Subjects.—There were 12 *S*s, men between the ages of 18 and 32, who had been selected for alpha of high incidence and amplitude. Of these, six were successfully conditioned. Experiments on four were terminated because, in the experimental sessions, which were held at night, it was found that their alpha rhythm was greatly depressed. This was due either to drowsiness or emotional disturbance of some sort. Two of those whose alpha remained satisfactory failed to reach the criterion of conditioning within the time limits set by circumstances.

Experimental Procedure.—One electrode was placed over the right occipital area, one over the right ear, and two over the flexor digitorum sublimus muscle on the inner part of the left fore-arm. The *S* lay on a bed, both hands open at the sides. The desired clenching of the fist was demonstrated as a rapid clenching and unclenching. After 5 to 10 practice trials, the *S* was addressed in the following manner:

"Continue clenching your fist that way two or three times a minute. The intervals don't need to be the same. Don't count; in fact, don't worry about the spacing at all. I'll let you know if you are going too slow or too fast."

After at least five control trials, conditioning was started. In reinforced trials, the beginning of every burst of muscle potentials was followed by a light of four to five sec. duration. The following orders of reinforcement were used for 10-trial periods: RURURRURUU, RUURURRURU, URURRURUUR. Thus one-half of all the conditioning trials were reinforced. Reinforcement was continued until, in two consecutive unreinforced trials, the alpha seemed completely depressed by the voluntary stimulus (AL index→o). The criterion of two consecutive CRs was used because of the conditions of reinforcement and then only for purposes of record taking. The criterion of conditioning used in treatment of the data was five consecutive unreinforced trials with a significantly [3] low AL index. Measurement of the records showed that only six *S*s were conditioned to this criterion.

Extinction to a criterion of five consecutive trials in which the CS had little or no effect on the alpha rhythm was carried out with but one *S*, owing to limitations of time. However, all the experiments were continued until the CS produced very little change in two consecutive trials. This makes possible a report on the early phases of extinction in all six *S*s. The 'expectancy' studies, to be described later, were carried out on four *S*s.

Treatment of Data.—The AL index (see above) was determined with the cumulative measuring device described previously (**14**). The segment of record measured was the 2-sec. interval beginning 0.67 sec. after the incidence of the fist-clench. The choice of this particular part of the record for measurement was arbitrary. It is the same segment measured in the previous study, where it was found suitable (**14**). The AL index of the 2-sec. segment preceding the CS was also measured.

[3] The critical ratio of the difference between the AL index of the controls and the first five trials had to exceed 3.0 in order to be considered significant.

Results

Acquisition

Results will be presented for the six *S*s who were conditioned to a criterion of five consecutive CRs.

The number of reinforced trials required to attain the criterion ranged from 11 to 49, with a mean of 24.5. Prior to reinforcement by light, the mean AL index of the 2 sec. of record following the voluntary stimulus (i.e., 0.67 to 2.67 sec.) was 71 (S.D. = 3.7). The mean AL index of the first five trials after the cessation of reinforcement was 18 (S.D. = 1.9). This highly significant difference (critical ratio = 12.6) indicates that conditioning took place. The data are presented in Table I.

TABLE I

Acquisition: No. of Reinforced Trials; AL Indices of the Controls and of the First Five CRs Following the Cessation of Reinforcement

Subject	1	2	3	4	5	6	Mean	S.D. Mean
No. Reinf. Trials	12	21	24	30	11	49	24.5	5.2
Control Index	64	72	64	71	66	90	71	3.7
CR Index	13	20	19	25	11	17	18	1.9

The course of acquisition was plotted in a Vincent curve. The average responses (AL index) during successive sixths of acquisition are given in Table II. The acquisition curve is shown in Fig. 1.

TABLE II

Successive Sixths of Acquisition (Six Ss) Pre- and Post-CS, Mean AL Index

Sixths	1	2	3	4	5	6
Pre-CS	68	65	66	60	53	59
S.D. Mean	5.2	3.0	5.2	5.7	6.8	5.7
Post-CS	67	51	46	43	33	11
S.D. Mean	2.5	6.4	7.0	6.1	5.8	3.0
Critical Ratio	0.2	2.0	2.3	2.0	2.2	7.5

In general, the curve is an accelerated one, the AL index changing from 67 to 11 with increasing speed as conditioning progresses. This accelerated curve resembles the usual curve of acquisition obtained for other types of CR (4, p. 145). It should be borne in mind that the shape of the curve is in part determined by the criterion of condi-

tioning used. Had a more rigid criterion been used, or had reinforcement been continued for a length of time following the attainment of the present criterion, we would expect to see the curve level off at the top.

Also shown in Fig. 1 is a curve revealing a concurrent change in the AL index of the 2-sec. interval just *preceding* the fist-clenching (Table II). This change is due, at least in part, to negative latency

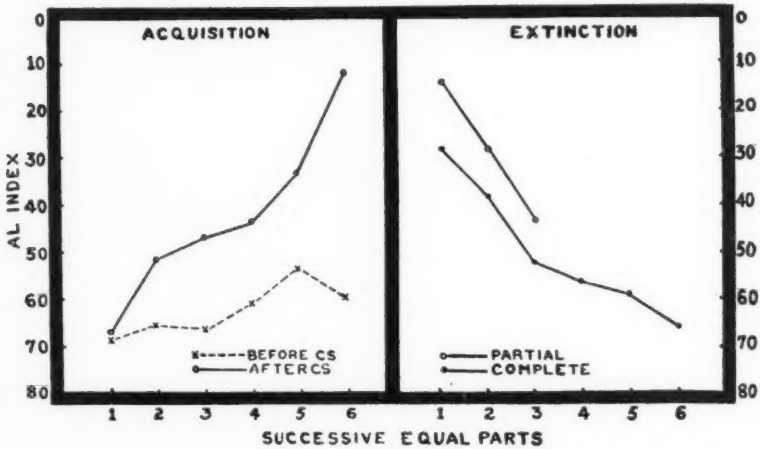

FIG. 1. Vincent curves of acquisition and extinction. On the left the solid line represents successive sixths in the acquisition of the response; the dotted line represents the concurrent changes in the 2 sec. of record *preceding* each CS during acquisition. On the right the partial extinction curve is for the six *Ss* on the present study. The complete extinction curve is reproduced from Shagass (14).

of the CR. In spite of this reduction in the Pre-CS AL index, there is still a highly significant difference between the Pre-CS and Post-CS alpha during the final sixth of acquisition (critical ratio = 7.5). This may be taken as a further indication and measure of the conditioning. The fact that these two curves become significantly different from one another during the final sixth of acquisition suggests that most of the conditioning occurred during this period.

'*Expectancy*'

The anticipation of the response, referred to above, is customarily found in delayed or trace CRs. In the present experiment it appears as a consequence of the voluntary nature of the CS. Although it is not of great magnitude, this anticipation suggests that part of the response might be correlated with an active conscious 'expectation' of the light.

The influence of such an attitude of 'expectancy' on the part of the response occurring *after* the CS was explored by noting the effect of instructions on the response to the CS. Four *S*s whose CR had been extinguished, or nearly extinguished, were told that they would be informed whether or not a light would follow the next few fist-clenches. The experimenter had been honest in all dealings with the *S* up to this point, and built up a further reputation for veracity by calling the next few trials correctly. For from three to five trials the light was promised and presented. Following this there were from three to seven trials in which no light was promised or presented. Then one or two lights were promised, but not presented.

The AL indices of the trials in which light was neither promised nor presented were divided into thirds and combined. The successive means were 31, 37 and 55 respectively. These figures yield an extinction curve, and show that the *S*s were responding to the CS even when they did not 'expect' a light. Unfortunately, it is impossible to compare this extinction curve with those of the main experiment because the prior reinforcement and the degree of conditioning attained were dissimilar. The mean AL index of the trials in which the *S* was deceived was 6, a definite response. This evidence that the alpha rhythm may be depressed by suggestion agrees with that of Loomis, Harvey, and Hobart (**11**) for *S*s under hypnosis. That CRs occurred when the *S*s did not expect the UCS indicates, however, that a conscious attitude of expectation is probably not a necessary factor in the elicitation of the response. These results do not eliminate the possibility that some *unconscious* set or attitude of 'expectancy' may be operating. They do limit the role of *conscious* 'expectancy' as controlled by verbal instructions. This is in agreement with the finding that voluntary factors are limited in delayed CRs to sound (**8**).

Extinction

Only one experiment in this study was continued until the CS had no effect on the alpha rhythm for five consecutive trials; in it, 38 extinction trials were required. This extinction series, when divided into successive sixths, gave a curve which resembled closely that for the seven *S*s in the previous study (**14**). The extinction data for this *S* and those of the earlier study are presented in Table III.

The extinction of the CR in the remaining five *S*s in the present study was continued until the CS had little effect in two consecutive trials. For all six *S*s, including the one whose CR was more completely extinguished, the number of unreinforced trials required to attain this criterion ranged from 7 to 26, with a mean of 12.3. When the average AL index for successive sixths is calculated, it is evident that extinction was far from completed. The mean AL index for

TABLE III

SUCCESSIVE SIXTHS OF EXTINCTION (MEAN AL INDEX)

Sixths	1	2	3	4	5	6
1 Subject (this study)	11	30	53	49	56	60
7 Subjects (previous study)	28	38	52	56	58	66

the fifth point was 31, while the mean index for the last point was 57 (Table IV). This would indicate that the failure to respond to the CS in two consecutive trials is probably a chance variation in the extinction process. Since extinction was not complete and the mean number of trials in these extinction series was about half that in the acquisition series, it was considered justifiable to plot a Vincent curve of extinction in successive thirds. The data thus obtained are shown in Table IV and plotted in Fig. 1.

TABLE IV

EXTINCTION TO A CRITERION OF TWO NO-CR TRIALS

Division	1	2	3	4	5	6
Successive Sixths	11	17	26	29	31	57
S.D. Mean	2.6	4.0	5.2	7.8	5.6	3.2
Successive Thirds	14	28	43			
S.D. Mean	2.3	1.8	2.7			

The extinction curve is almost a straight line in its descent from a mean AL index of 14 for the first point to one of 43 for the third point. It is nearly the mirror-image of the last half of the acquisition curve, which is derived from the same average number of trials. It also has the same shape as the first half of the extinction curve obtained in the previous study (Fig. 1), but is consistently above it. The first point of the present extinction curve is 14 (S.D. = 2.3), while the first point of the other is 28 (S.D. = 2.0). This difference is significant (critical ratio = 4.6). Since there were more reinforced trials in the experiments of the earlier study (mean = 36.9), it appears that intermittent reinforcement will produce a CR of greater magnitude than will massed reinforcement. This finding agrees with the observation that "spaced practice favors conditioning over massed practice" (4, p. 148), and suggests that 'inhibition of reinforcement' may have been operating in the massed procedure (5).

Discussion

It has been shown that depression of the occipital alpha rhythm can be conditioned to voluntary clenching of the fist, if one-half of all the voluntary movements are reinforced by light. With this technique an accelerated curve of acquisition may be traced. This acquisition curve is nearly the mirror-image of the decelerated extinction curves obtained in this study and in a previous study of the same response. The results indicate that the course of acquisition and extinction in EEG conditioning is similar to that usually observed in the more conventional types of conditioning. It was also shown that the CR was maintained for several trials (with diminishing strength) even though the *S*s knew that no light would be presented. This indicates that the response depends on more than the *S*'s conscious 'expectation' of the light.

The relatively rapid extinction of the CR is a point of interest. Culler (**3**) and Brogden, Lipman and Culler (**1**) have suggested that extinction is an inverse conditioning which takes longer than acquisition in the usual conditioning experiment, because the situation provides a strong incentive (e.g., shock or food) for the building up of a CR, as opposed to the weak incentive for extinction provided by inertia. When extinction is reinforced by a stronger incentive (thoracic shock), the animal is restored to its pre-conditioning state in as short a time as it takes to bring about conditioning. Mowrer and Lamoreaux (**12**) have also pointed out that a response conditioned in the classical manner is not perpetuated unless it is 'successful.' In conditioning the alpha rhythm, acquisition and extinction each require an approximately equal number of trials. This similarity in the duration of the acquisition and extinction processes is interesting in the light of the 'inverse conditioning' theory of extinction—especially since it is easy to assume that the 'reward' or lack of 'reward' is equal for both processes in the present experiment. Since the response measured is entirely outside the knowledge of the *S*, and the effect of conscious 'expectancy' has been shown to be limited, the 'reward' demanded by the law of effect is not provided at a conscious level. The CR of the alpha rhythm probably represents a fairly pure case of stimulus-substitution and, when reinforcement ceases, it is inversely conditioned about as readily as it was formed. It would be interesting to observe the effect 'over-conditioning' might have on the shape of this extinction-curve.

Jasper and Shagass (**7**) have suggested that the conditioning of the electrical activity of the cortex represents some evidence for the theory that a facilitation process underlies stimulus-substitution in conditioning. They state:

"Repeated paired presentation of sound and light gradually lower the threshold of certain pre-existing synaptic pathways . . . so that auditory stimuli temporarily become effective in desynchronization of the occipital alpha rhythm" (p. 386). Although it is realized that the effect of volition cannot be entirely excluded, with the substitution of "proprioceptive" for "auditory" in the above statement, it may well describe what happens in the present experiment. The acquisition curve for the CR to fist-clenching would then represent the progressive recruitment of synaptic pathways involved in desynchronization of the alpha rhythm. More definite verification of this hypothesis would require animal experimentation. There is some evidence that the electrical response of the visual cortex in the cat can be conditioned to an auditory stimulus (**15**). Although incomplete, this experiment indicates the feasibility of work along these lines.

In this study further resemblances have been shown between alpha-block conditioning and conditioning at the peripheral level. No new conditioning concepts are necessary in the treatment of the response. On the other hand, the CR is unique in that it is an electrical response of cortical tissue. It may be spoken of in neurophysiological terms and represents a central neurophysiological parallel of events which have usually been observed at the periphery. Insofar as conditioning was first undertaken by Pablov (**13**) as the study of cortical function, the EEG method seems to provide a more direct technique than one using responses of peripheral effectors for the verification of hypotheses concerning cortical function. It is probable, however, that functionally this cortical response is still 'peripheral' to the fundamental neurophysiological changes involved in the process of conditioning.

Summary

1. The acquisition curve for the conditioned response of the occipital alpha rhythm to voluntary clenching of the fist was determined by using a conditioning procedure in which one half of the trials were reinforced. The curve was an accelerated one, nearly the mirror-image of the extinction curve. The curves of acquisition and extinction for EEG conditioning are similar to those obtained when peripheral responses are conditioned.

2. The effect of a conscious attitude of 'expectancy' was investigated by telling the *S*s whether or not to expect a light. It was found that, after a short reinforcement series, responses were given when a light was not 'expected.' These trials yielded an extinction series. Responses were always given when light was expected. It

was concluded that the effect of conscious 'expectancy' in the formation of the conditioned response is limited.

3. The results were discussed from the viewpoint of established conditioning concepts.

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References

1. Brogden, W. J., Lipman, E. A., & Culler, E. The role of incentive in conditioning and extinction. *Amer. J. Psychol.*, 1938, **51**, 109–118.
2. Cruikshank, R. M. Human occipital brain potentials as affected by intensity-duration variables of visual stimulation. *J. gen. Psychol.*, 1937, **21**, 625–641.
3. Culler, E. Recent advances in some concepts of conditioning. *Psychol. Rev.*, 1938, **45**, 134–153.
4. Hilgard, E. R. & Marquis, D. G. *Conditioning and learning.* N. Y.: D. Appleton-Century Co., 1940.
5. Hovland, C. I. "Inhibition of reinforcement" and phenomena of experimental extinction. *Proc. nat. Acad. Sci.*, Wash., 1936, **22**, 430–433.
6. Jasper, H. H., & Cruikshank, R. M. Electroencephalography II: Visual stimulation and the after-image as affecting the occipital alpha rhythm. *J. gen. Psychol.*, 1937, **17**, 29–48.
7. Jasper, H., & Shagass, C. Conditioning the occipital alpha rhythm in man. *J. exp. Psychol.*, 1941, **28**, 373–388.
8. Jasper, H., & Shagass, C. Conscious time judgments related to conditioned time intervals and voluntary control of the alpha rhythm. *J. exp. Psychol.*, 1941, **28**, 503–508.
9. Knott, J. R., & Henry, C. E. The conditioning of the blocking of the alpha rhythm of the human electroencephalogram. *J. exp. Psychol.*, 1941, **28**, 134–144.
10. Loomis, A. L., Harvey, E. N., & Hobart, G. A. Electrical potentials of the human brain. *J. exp. Psychol.*, 1936, **19**, 249–279.
11. Loomis, A. L., Harvey, E. N., & Hobart, G. A. Brain potentials during hypnosis. *Science*, 1936, **83**, 239–241.
12. Mowrer, O. H., & Lamoreaux, R. R. Avoidance conditioning and signal duration—a study of secondary motivation and reward. *Psychol. Monogr.*, 1942, **54**, No. 247, 34 pp.
13. Pavlov, I. P. *Lectures on conditioned reflexes.* Trans. by W. H. Gantt. N.Y.: Int. Publishers, 1928.
14. Shagass, C. Conditioning the human occipital alpha rhythm to a voluntary stimulus. A quantitative study. *J. exp. Psychol.*, 1942, **31**, 367–379.
15. Shagass, C. Conditioning the electrical response of the visual cortex in the cat. Unpublished M.S. thesis, University of Rochester, Rochester, N. Y., 1941.
16. Travis, L. E., & Egan, J. P. Conditioning of the electrical response of the cortex. *J. exp. Psychol.*, 1938, **22**, 524–531.

A COMPARISON OF EYELID RESPONSES CONDITIONED WITH REFLEX AND VOLUNTARY REINFORCEMENT IN NORMAL INDIVIDUALS AND IN PSYCHIATRIC PATIENTS

BY H. E. KING AND CARNEY LANDIS

Psychiatric Institute, Columbia University

It is customary to think of the conditioned response situation as one in which an unlearned reaction is utilized as reinforcing response; viz., the eyelid closure is a natural response to a puff of air directed against the eyeball. In reality, many additional methods of unconditioned reinforcement have been utilized, the assumption being that the response is the essential thing and that the stimulus is secondary (**3, 11**). Marquis and Porter (**7**), believing it reasonable to assume that the method of eliciting response would be an important variable in determining the type of reaction obtained, conducted experiments in which they conditioned the eyelid response. They made a qualitative and quantitative comparison of responses with reflex reinforcement as against responses with voluntary reinforcement, bringing out the differential characteristics of the 'types' of conditioning. From the Marquis and Porter data, Irwin (**6**) has taken as one of the criteria of voluntary activity the fact that conditioning with voluntary reinforcement is more subject to a change in instructions (set) than is that which is reinforced by reflex. It is the purpose of the present report:

1. To repeat the Marquis and Porter experiment for purposes of comparing the responses of the normal with those of the psychiatric patient. It is a common clinical assumption that an outstanding deviation in the mental patient is a disorder of volition, either in behavior or in the mental life. Hence it seemed worthwhile to ascertain whether or not the same functional characteristics of response will hold with mental patients.

2. To compare the effect of change of set by instruction for the normals and patients with both voluntary and reflex reinforcement of the conditioning.

3. To examine the retention of conditioned responses both with reflex and with voluntary reinforcement following a time lapse, in both normals and patients.

For purposes of valid comparison the situations for reflex and

voluntary reinforcement have been made as nearly identical as possible. The two types of reinforcement used were:

1. *Reflex Reinforcement.*[1]—A peripheral light increase in brightness, which evoked minimal or no lid reflex, was paired at an interval of 400 milliseconds (σ) with an air puff stimulus to the right eye which evoked a brisk, maximal corneal reflex.

2. *Voluntary Reinforcement.*—The same brightness change of the peripheral light was paired at an interval of 300σ [2] with a sound stimulus of variable intensity. (The relative loudness of a click was adjusted so that no wink would occur in response to the click itself.) The *S*s were instructed to wink as rapidly as possible to the sound stimulus.

In the normal individual and in the psychiatric patient comparisons of the two 'types' of conditioned response were made with regard to: (1) the course of acquisition and the descriptive characteristics of each, and (2) the effects of a change in set upon the extinction of each.

Procedure

Apparatus

Stimulus and response time were recorded by the amplification of the muscle currents produced by the contraction of the tarsal portion of the orbicularis major during eyelid closure and the recording of these amplified currents by means of electrically driven ink writers. A flat electrode was placed on the eyelid just under the eyebrow and a circuit formed by attaching the indifferent electrode to the lobe of the ear.

Timing was standardized by means of a gear-driven commutator, appropriate speeds being set by variac control of the driving motor. The point of stimulation was indicated by momentary electrical pulses delivered to the ink writers.

Automatic delivery of the air puff, which acted as the stimulus that elicited the reflex response, was effected by a nozzle directed toward the outer canthus of the right eye. The strength of the puff was adjusted to elicit maximal response in all *S*s.

The auditory stimulus for the voluntary response was a click in a set of headphones worn by the *S*.

The *S* was seated in a light-proof, semi-sound-proof, electrically screened and grounded compartment. His head was stabilized by a brace giving contact to the chin and forehead. At a verbal ready signal, which preceded the conditioned stimulus by a randomly varied interval of from two to eight sec., the *S*s looked at an illuminated oval window of milk-glass placed at a distance of 100 cm. from the fixed eye position, in the center of which was a black cross to serve as fixation point. The conditioned stimulus was an increase in brightness of a peripheral light, from 0.2 to 0.4 apparent foot-candles, as measured at the eye position. This variable light was set at an angle 10° lateral to the line of fixation. The slight increase in brightness was clearly discernible in the darkness of the experimental compartment. A sound screen was used throughout to equate any incidental noise which might be audible through walls of the semi-soundproof compartment.

[1] Time intervals and reinforcements of Marquis and Porter (7) were followed as nearly as possible in order to make the studies directly comparable.

[2] Because the latency of the voluntary response is greater than that of the reflex response, the time interval was made shorter so that the reinforcing responses occurred at approximately the same interval (450σ) following the conditioned stimulus in each case.

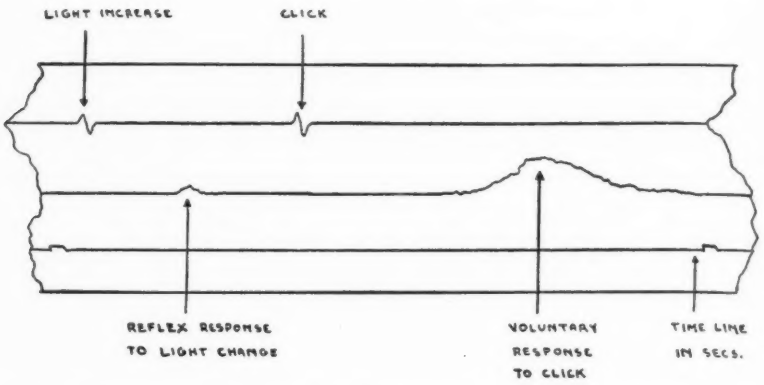

FIG. 1. Diagrammatic sketch of a record of the voluntary reinforced response before conditioning.

SUBJECTS AND EXPERIMENTAL PLAN

Normals were chosen from an experimentally unsophisticated group (five women and three men) and the patients were chosen in terms of their hospital diagnosis in order to provide some degree of sampling [five women and three men, two of whom were diagnosed as schizophrenic, two as paranoid, two as manic-depressive (depressed) and two as neurotic]. The age range of both normals and patients was from 17 to 35 years. No one of the *S*s was acquainted with the nature or the purpose of the experiment. Table I diagrams the experimental set-up demonstrating the group and subgroup division. No *S* was used more than once.

TABLE I

EXPERIMENTAL DESIGN

	Number of Subjects	Method of Conditioning	Method of Extinction
Normals	4	Reflex-Reinforcement	2 Experimental 2 Instructed
	4	Voluntary-Reinforcement	2 Experimental 2 Instructed
Patients	4	Reflex-Reinforcement	2 Experimental 2 Instructed
	4	Voluntary-Reinforcement	2 Experimental 2 Instructed

PROCEDURE AND RESULTS

Conditioning with Reflex Reinforcement in the Normal (RCR–N)

The establishment of a conditioned eyelid response to a change in brightness reinforced by the corneal reflex to an air puff was studied

in four normal *S*s. The experimental conditions are as similar as possible to the studies of Hilgard and Campbell (4) and Marquis and Porter (7). The conditioned stimulus was an increase in the brightness of the peripheral light. The apparatus was adjusted to give maximum comfort to the *S* and the instructions were given: "I want you to sit completely at ease and relaxed. When I call 'Ready,' fix your eyes on the small black cross; keep looking steadily, without blinking, at the cross until I call 'Rest.' After I say 'Rest' you may rest your eyes in any way that you wish until I call 'Ready' again. Then I want you to look steadily again, without blinking, at the cross until I call 'Rest'; and so on. Do not move your head from the fixed position; rest periods will be given periodically so that you may rest your head and shoulders."

Paired stimulations were begun and continued until conditioning had taken place. Trials were separated by intervals of from 20 to 40 sec., rest periods being allowed after each series of 15 trials. Conditioning in the normal occurs, usually, at about 30 to 40 trials; the number of trials necessary seeming to be a function of individual difference [Hilgard and Campbell (4), Campbell and Hilgard (1)].

The average of the time between the presentation of the stimulus and the start of the normal eye wink was obtained from the first five responses in the experiment. This average we shall call 'reflex latency' and use as an indicator of the normal eyelid closure time. This average was determined for each individual *S*. In the conditioning experiments, all responses which were more rapid than the individual's reflex latency were considered to be his conditioned responses. Reaction times varied from 158 to 236σ with a mean of 191σ. Application of a more strict criterion (considering as conditioned only those responses which actually preceded the reinforcing stimulus) reduces the number of responses that would be considered to be conditioned, but fails to bring about any change in the trend of the results. The conditioned criterion was set at that point at which the response was well below the previously described reflex latency time, viz., 30 to 40 trials, and when it had become constant over a series of trials. Trials were ceased as soon as conditioning by such standards could be ascertained, in order to hold constant any degrees of overlearning.

The conditioned response obtained with reflex reinforcement is characterized by its slow, gradual development. It first appears as a very weak response which increases in amplitude and frequency of occurrence during training. The latency is reduced by training until it follows the conditioned stimulus by an interval approximately equal to the latency of a voluntary reaction to the conditioned stimulus. This type of response resembles closely the traditional condi-

tioning, as most of these studies are done with reflex reinforcement. The general course of acquisition is represented graphically by an ogival or S-curve (4). This group will be referred to, for purposes of convenience, as *RCR–N* (reflex-reinforced conditioned response in the normal).

Experimental extinction was carried out in two of the *S*s, and the other two *S*s were given instructions not to wink, i.e., they were given an inhibitory set.

Experimental Extinction of the RCR–N.—The response was extinguished with a series of repetitions, disappearing with the 8th or 10th trial. Care was taken not to halt the extinguishing trials prematurely. There was a lengthening of latency during the process of extinction, and a gradual decrease of both amplitude and frequency until no response was obtained. Some irregularity of response was present.

Instructed Extinction of RCR–N.—Despite instruction to inhibit all response, the *S*s were not able to gain immediate control over the reaction. The reinforcing puff was not presented, and instruction was to inhibit all wink movements. A series of responses was obtained, as in the straightforward experimental extinction, the inhibitory set manifesting itself by weaker responses in a shorter series. The first one or two responses of the extinguishing trials were as vigorous and rapid as those of the experimentally extinguished group, but the third or fourth response and those following were weaker with lengthened latency.

Voluntary Reinforcement of Conditioning in the Normal (VCR–N)

The acquisition of *VCR*s was studied in four normal *S*s. The only change in apparatus was the substitution of a click, as the reinforcing stimulus, for the previously used puff of air. The instructions differed only by the addition of directions for the voluntary wink to the click. Trial procedure was identical with the *RCR*.

The type of conditioning which develops is fundamentally different from that obtained using reflex reinforcement. The lid closure is brisk and complete; the same response as an instructed voluntary wink. The latency of response ranges from 251σ to 858σ, with a median of 357σ. Little change in the type of response or its amplitude occurs in the course of development. The response appears within the first few trials and continues irregularly, without significant shortening of latency, during further training. The amplitude of the response, usually being a complete lid closure, does not vary.

Experimental Extinction of the VCR–N.—The *VCR–N* undergoes rather abrupt extinction after two or at the most three unreinforced

trials. The first response is brisk and resembles those of the trial series; subsequent responses are weak. Once the response has ceased it does not subsequently reappear.

Instructed Extinction of the VCR–N.—Instructions to refrain from winking ("Do not wink at all") did not suffice to inhibit the response altogether. As with the experimental extinction of the *VCR–N*, two and three responses were obtained, but these were very weak and of much smaller amplitude than those extinguished experimentally. Once the extinction was complete no subsequent response was made over a series of trials. (Though they might have grasped the idea, the *S*s were not informed, at the time inhibitory instructions were given, that the click was to be abandoned.)

Reflex Reinforced Conditioning in the Patient (RCR–P)

The patients provided little or no significant difference from the normals in the course of acquisition of reflex reinforced response. Amplitude of response was somewhat stronger, but reaction time and latencies showed no deviation from the normal. Conditioning usually occurred in fewer trials and the performance, on the whole, was more regular than that observed in the normals. In general, this is in keeping with the findings of Schlosberg (**12**) and Yacorzynski and Guthrie (**16**) that excited *S*s condition somewhat more easily, since it is possible that the patients may have been more excited by the laboratory situation than the normals.

Experimental Extinction of the RCR–P.—The response continued to appear during six to nine trials, with gradual decline in amplitude and general lengthening of latency, until no response was obtained. As with the normals, there was some irregularity of response during the extinguishing series.

Instructed Extinction of the RCR–P.—Results are numerically divided on this point as one patient gave four serial responses and the other 10. Actually this difference is not as great as the figures would indicate, as the weakening of response appeared with the third response (as in the *RCR–N*) and many of the subsequent responses were very slight. All responses obtained were weaker than those observed in experimental extinction.

Voluntary Reinforced Conditioning in the Patient (VCR–P)

Here again there were no observable differences between the normals and the patients in the course of acquisition of *VCR*s. Voluntary reaction time, amplitude of response, and latency of response did not deviate from the form taken in the normal. About

the same number of trials were necessary to reach our criterion and no excess irregularity of response was present.

Experimental Extinction of the VCR–P.—The extinction was not quite as abrupt as in the normal; four responses (compared to three responses) were obtained from each patient, the last two being quite weak but still clearly evident. Apparently there was slightly more perseveration of the learned activity with these four patients.

Instructed Extinction of the VCR–P.—In spite of the attitude set up by the instructions three responses were obtained, the initial response being quite brisk but the second and third were progressively weaker, showing smaller amplitude and lengthened latency.

Re-test and Extinguishing Trials Following Time Lapse

Three of the *RCR–N Ss* were tested at intervals of 9, 11, and 12 weeks after the original conditioning. The response was found to be present in all cases; but a weaker response with a tendency to slightly lengthened latency as compared with the original conditioned response.

Two of the *RCR–P Ss* were tested after a time lapse of 9 and 10 weeks. As with the normals the response was found to be present though much weaker with a tendency to lengthened latency.

Three of the *VCR–N Ss* tested after time lapses of 8, 8, and 9 weeks showed the response to be clearly evident, although weaker and more irregular than the original extinguishing series.

Four *VCR–P Ss*, two tested after a time lapse of 4, and two after a lapse of 8 weeks, also showed the response to be present, though weakened and irregular.

Summary

The results indicate quite clearly that the type of conditioned response developed with voluntary reinforcement is distinct from that established by reflex reinforcement. The types described were found to hold equally well for both the normal *Ss* and the mental patients. The *RCR* is a slowly, gradually developed conditioned response. It appears first as a weak response (partial closure) which increases in amplitude and frequency of occurrence during training. Its latency reduces until it follows the conditioned stimulus by an interval roughtly equal to the latency of a voluntary reaction to the conditioned stimulus. It is extinguished gradually during a series of trials. An inhibitory set does not succeed in greatly reducing the number of trials necessary for extinction.

The *VCR* occurs as a more or less abrupt development. Closure is complete; the same type of response as the instructed wink. The

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VCR appears within the first few trials and continues with little change in the type of response or in its amplitude and latency throughout further training. Its extinction is also somewhat abrupt, as two trials serve to wear it out. Inhibitory set weakens but does not abolish this short extinction series. The fact that inhibitory set is able to weaken but not extinguish the response, that the reflex and the voluntary conditioned responses are found to be retained following rather large time lapses, and that spontaneous recovery of the voluntary reinforced response occurs, all constitute direct evidence that the *VCR* is a true form of the conditioned response.

Since it is a common observation that some degree of 'will-impairment' is present in the psychiatric patient, it was thought that the acquisition of *VCR*s by the patient might show a difference from their course of development in normal individuals, or that it might show a similarity to the *RCR* type. This did not prove to be the case, and as the peculiar characteristics of the two types of conditioning are also obtained in the mental patient it would seem that the task is too simple, or of such a low order of voluntary activity that it fails to bring evidence of a will-impairment in the patient.

It was thought possible, at the outset, that the varied types of extinction set might differentiate by evidences of perseveration or suggestibility in either the normal or the patient. The patients required a slightly longer series of experimental extinction trials for the *VCR*, but the difference was slight and the number of cases too few to merit positive conclusions on this effect.

As the peculiar characteristics of the two types of conditioning are not essentially different between normals and patients we conclude that the task is too simple to afford evidence of will-impairment in the patient.

Discussion

The definition of what constitutes a voluntary action is by no means simple. Hence, we cannot make a clear-cut dichotomy between voluntary and involuntary responses in conditioning. Are we justified in speaking of voluntary conditioning at all? The evidence of this study and of other investigations [Wickens (**15**), Peak (**9**), Stephens (**14**), Yacorzynski and Guthrie (**16**), Marquis and Porter (**7**)] support the existence of such a distinction. If we agree with Marquis and Porter (**7**) that the conditioning situation be defined as the repeated presentation of an indifferent stimulus in a definite temporal sequence with a stimulus which naturally evokes a response, then the conditioned response may be defined as that response which in time comes to be elicited by the indifferent stimulus alone. There is nothing in such a point of view to deny the use of voluntary action

as a response capable of becoming conditioned. Rexroad (11), in testing the hypothesis that voluntary reactions can be conditioned, presents a considerable body of evidence in favor of such an assumption.

Gibson (2) denies the existence of such a variety of conditioning, and interprets the occurrence of such phenomena as being of similar nature to the false reactions obtained in a reaction-time experiment. He holds that the so-called voluntary conditioned responses are merely false responses, occasioned by sensory generalization, which are set off by the signal of the appearance of the conditioned stimulus. What is this but conditioning? If Gibson's concept is correct, there should be no regularity in the formation or the extinction of the *VCR*, for false responses are not invariably made. The evidence of this report and of those studies of voluntary reinforced conditioning previously cited demonstrates an indisputable pattern of acquisition, not a series of random responses. Introspection on the part of the *S*s participating in this study showed that they failed to attribute any significance at all to the increased brightness of the peripheral light with regard to the carrying out of instructions to respond to the sound of a click.

A further point indicating that the *VCR* is a form of conditioning is brought out by our data. *VCR* was shown to exhibit the post-extinction recovery after a lapse of several weeks, a phenomenon not easily explained in terms other than those of conditioning.

Although the question of whether there can be true voluntary conditioning is far from being conclusively settled, the phenomenon does occur and the present state of experimental evidence would argue for its being one type of conditioned response.

What, then, is the place of conditioning studies in the field of volition? Is there enough of a voluntary element present to consider the phenomena of conditioning a 'physiological index' of the working of the will?

The *VCR* gives every indication of being a voluntary action which has shifted over into the realm of the involuntary. The fact of this occurrence has been cited often enough, but investigators have been reluctant to call it a true conditioning, probably because of its rather unique course of acquisition. Marquis and Porter (7) have shown [and Irwin (6) has included as one of his definitions of volition] that voluntary reinforced conditioning is more subject to a change of set, by instructions or by the alteration of the physical situation, than is reflex reinforced conditioning. That is to say, a shift in the attitude of the *S* has more influence on voluntary conditioning than on reflex conditioning. A voluntary response elicited by a conditioned stimulus is much more within the scope of conscious control

than is a reflex or unwilled reaction to a conditioned stimulus. Thus, the associative process of the higher cortical functions is qualitatively different from the associative process of reflex activity. The data of this study indicate quite clearly that *RCR* is also subject to changes of set, but to a much less significant degree. These results are consistent with those of Razran (**10**) and Hilgard and Humphreys (**5**). This serves to indicate that if the *RCR* can be influenced by voluntarily induced sets, then a voluntary element is present.

Because the conditioned act is a simple, yet novel task, the effects of varied set should be largely comparable between individuals. This enhances the possible value of such conditioning studies with mental patients, hypnotized *S*s, the feebleminded, etc., where there is thought to be a psychopathology of volition. By thus delimiting the action under study the place of will in such action may be observed more closely.

Perseverational tendencies were investigated in catatonic patients by Mays (**8**) and in schizophrenic patients by Shipley (**13**). The indicator used in both studies was the conditioning of the psychogalvanic reflex. They report a marked perseveration of the conditioned response, which in this instance is a purely autonomic activity. The present study gives reason to believe that there is a similar perseveration of the *VCR* within this limited sample of psychiatric patients. The existence of experimental evidence such as this gives much promise to the method as a technique which may be further developed to add to our knowledge of the basic psychology of the abnormal.

Conclusions

A comparison of eyelid responses conditioned with reflex and voluntary reinforcement in normal individuals and psychiatric patients indicates that:

1. Although the same wink movement was under study in each case, the type of conditioning which arises through voluntary reinforcement differs from that arising through reflex reinforcement in its descriptive characteristics, its course of development and in its type of extinction. *VCR*s exhibit the post-extinction recovery with lapse of time of a characteristic fashion as do *RCR*s.

2. There are negligible differences in the course of acquisition of either the *RCR* or the *VCR* between normal individuals and psychiatric patients.

3. There is some evidence of a greater perseveration of the learned activity of the *VCR* in psychiatric patients.

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References

1. Campbell, A. A., & Hilgard, E. R. Individual differences in ease of conditioning. *J. exp. Psychol.*, 1936, **19**, 561–571.
2. Gibson, J. J. A critical review of the concept of set in contemporary experimental psychology. *Psychol. Bull.*, 1941, **38**, 781–817.
3. Guthrie, E. R. *The psychology of learning.* New York, Harper & Brothers, 1935, p. 37.
4. Hilgard, E. R., & Campbell, A. A. The course of acquisition and retention of conditioned eyelid responses in man. *J. exp. Psychol.*, 1936, **19**, 227–247.
5. Hilgard, E. R., & Humphreys, L. G. The effect of supporting and antagonistic voluntary instructions on conditioned discrimination. *J. exp. Psychol.*, 1938, **22**, 291–304.
6. Irwin, F. W. The concept of volition in experimental psychology. In: *Philosophical Essays in Honor of Edward Arthur Singer.* Philadelphia, Univ. of Penna. Press: 1942, pp. 115–137.
7. Marquis, D. G., & Porter, J. M. Differential characteristics of conditioned eyelid responses established by reflex and voluntary reinforcement. *J. exp. Psychol.*, 1939, **24**, 347–365.
8. Mays, L. L. Studies of catatonia. V. Perseverational tendencies in catatonic patients. *Psychiat. Quart.*, 1934, **8**, 728–735.
9. Peak, H. An evaluation of the concepts of reflex and voluntary action. *Psychol. Rev.*, 1933, **40**, 71–89.
10. Razran, G. H. S. Conditioned responses: An experimental study and theoretical analysis. *Arch. Psychol.*, 1935, **28**, No. 191.
11. Rexroad, C. N. Reaction time and conditioning: First studies. *J. exp. Psychol.*, 1936, **19**, 144–158.
12. Schlosberg, H. An investigation of certain factors related to the ease of conditioning. *J. gen. Psychol.*, 1932, **7**, 328–342.
13. Shipley, W. C. Studies of Catatonia. VI. Further investigation of the perseverational tendency. *Psychiat. Quart.*, 1934, **8**, 736–744.
14. Stephens, J. M. Data bearing on the conditioning of voluntary reactions. *J. exp. Psychol.*, 1937, **21**, 236–239.
15. Wickens, D. D. A study of voluntary and involuntary finger conditioning. *J. exp. Psychol.*, 1939, **25**, 127–140.
16. Yacorzynski, G. K., & Guthrie, E. R. A comparative study of involuntary and voluntary conditioned responses. *J. gen. Psychol.*, 1937, **16**, 235–257.

STUDIES OF RESPONSE GENERALIZATION IN CONDITIONING. I. STIMULUS GENERALIZATION DURING RESPONSE GENERALIZATION

BY DELOS D. WICKENS

University of Wisconsin

Introduction

Most investigations in the field of conditioning have been concerned primarily with the effect upon the conditioned response of variations of the two important conditioning stimuli—the conditioned and the unconditioned. Studies have been conducted to determine what conditioned and what unconditioned stimuli can be used, how variations in the frequency or consistency of presentation of the two stimuli affect the response, and how different time relations affect the response. In short, the concern of these investigations has been directed toward discovering how historical conditions affect the present conditioned response behavior. Needless to say, such researches have contributed greatly to our knowledge of behavior under certain well-defined conditions.

The very nature of these studies has demanded that all of the environmental conditions other than the conditioned and the unconditioned stimuli be held constant. The behavioral records of such experiments have pointed toward a moderately high degree of constancy in the form of the response, and toward a disturbance of the conditioning process with the introduction of new stimuli (external inhibition). As a consequence of these findings, many psychologists have been led to conceive of the conditioned response as a behavioral segment which is both fragile and rigid; a unit which is either shattered completely by any shift in the stimulating situation, or one which stubbonly maintains the same form in the face of wide environmental changes.

Such a view makes the conditioned response something of a psychological hot-house plant, a concept which may be amusing to play with in the laboratory, but which does not hold up in the rigors of everyday life where one finds not only variation in the environment, but equally wide variations in the response to a given stimulus. Conceiving of the conditioned response in this manner, many psychologists have rejected it as having little value in understanding behavior outside of a few restricted laboratory situations.

In the light of such criticisms of conditioning, and in view of the fact that if they are true, the conditioned response is indeed of limited theoretical value, a fruitful direction to research in the field of conditioning may be toward determining if and how the conditioned response will vary in its characteristics as a result of variations of the environment or of the subject's relation to his environment. Essentially such research would consist of developing the conditioned response, and then presenting the conditioned stimulus under altered conditions and assaying the functional relationship between these variations and the conditioned response. Only after research of this sort has been done is one in a position to appreciate the significance of the conditioned response in the extra-laboratory situation in which a constant environment is the exception rather than the rule.

Some experimental work of this sort has already been done. Thus, we know that a functional relationship exists between an already established conditioned response and motivational states (**2**, **14**), emotional conditions (**6**, **7**), and the general condition of the organism (**11**). In the case of the operant conditioned response there are data to indicate that the significance of the conditioned stimulus may carry over into a situation widely different from the one in which it acquired its significance (**10**).

Problem

The purpose of the present experiment was to investigate the operation of stimulus generalization during response generalization. Specifically, the experiment was designed to determine whether or not a changed response would be given to stimuli other than the one to which the *S* had been conditioned.

In several previous studies (**12**, **13**) the writer has indicated that the form of the response can be radically altered by environmental changes. In these experiments an extension response of the finger was first conditioned, and then the hand was turned over and the same finger was placed on the electrode. Though the apparatus was constructed so that either an extension or a flexion could be made with equal ease, it was found that the *S*s characteristically flexed, rather than extended, the finger when the conditioned stimulus alone was presented. Such a modification of the form of the response without additional training is an instance of response generalization (**3**, p. 350).

The facts of stimulus generalization are well known. Pavlov (**7**) reported that animals trained to a specific stimulus will react to others which differ from it along the same psychological dimension. More recently in this country several careful studies have been con-

ducted on this phenomenon (**1**, **4**, **5**, **8**), and have given more precise information concerning its operation. In general, these studies have indicated that generalization does occur, and that the magnitude of the generalized response is a function of the degree of similarity of the generalized to the original stimulus.

Subjects

The 59 *S*s who took part in the experiment were all enrolled in the Elementary Psychology course at the University of Wisconsin. They were about equally divided as to the sexes.

Apparatus

The conditioning board used in the experiment was wooden, and similar to that described in a previous experiment (**12**). The *S*'s arm was restrained to a board 12 in. × 30 in. by a wooden block at the elbow, a leather strap across the forearm, and a rigid wooden strap that could be clamped down across the back or the palm of the hand, depending on the position of the *S*'s hand on the board. The location of these restrainers on the board could be adjusted to the size of the *S*'s arm. The *S*'s middle finger rested on an electrode about the size of a dime. This electrode was fastened to a platform supported by a spring. Since the tension of the spring was slight, the entire platform could be easily depressed by the *S*. Movements of the finger either upwards or downwards were recorded by means of electrical contacts. Downward movements were recorded when a bolt head attached to the electrode platform dipped into a mercury well. Upward movements were recorded when a metal strip resting on the *S*'s finger came into contact with a brush just above the strip. Both recording mechanisms were adjustable, and were arranged so that movements of about 1/16 in. in either direction were recorded. The other electrode was strapped to the *S*'s wrist.

The conditioned stimulus was produced by a Maico Audiometer, and was delivered into an earphone worn by the *S*. The unconditioned stimulus was produced by a high voltage power pack. The temporal relations between the two stimuli, as well as the duration of the individual stimuli, were controlled by lugs on a timing disk operated by a one r.p.m. synchronous motor. As the disk revolved, the lugs made contact with their appropriate brush; this closed several relay circuits which started the clock and administered the tone and the shock. The clock, which measured time in units of .01 sec., started 1/2 sec. before the tone was given, and continued until the *S*'s response broke the circuit of its holding relay. The clock could be stopped by either an upward or downward response, and the direction of the response was indicated by lights on a control panel. The duration of the tone was 1/2 sec., and its termination coincided with the termination of the shock. The shock persisted for 1/10 sec. The control panel permitted *E* to administer either stimulus independently, and to vary the inter-trial time intervals.

E and the apparatus were in adjacent rooms. The two rooms were sound-proof from the rest of the building and from each other. The *S* could be observed, however, through a one-way-vision screen.

I. Experimental Procedure

The general procedure used throughout the experiments for the three experimental groups was that of conditioning the *S*s to one tone, turning the hand over, and testing for responses to the same tone, or to a tone differing from this by either one or two octaves.

The *S* was first brought into the experimental room, and the following directions were given:

> "This is a conditioning experiment. During the experiment your hand will be strapped to this board, with your middle finger resting on this electrode, and the other electrode fastened to your wrist. You will receive a shock which will pass from one electrode to another. You can break the shock by lifting your finger from the electrode. During the experiment a tone will precede the shock by a regular interval of time. If you get conditioned you will develop a tendency to respond to the tone before the shock goes on. I do not want you to fight against becoming conditioned, and at the same time you are not to respond voluntarily to the tone. If your finger wants to fly up just don't inhibit it.

"I will start the experiment by obtaining your threshold to a tone. I will begin with a tone which will be clearly heard, and reduce the intensity of it until you cease to hear it. Then, using the same tone, I will increase its intensity until you hear it again. I want you to press on this button all the time you hear the tone.

"I will test for two tones in the same way.

"Following that I will test for the strength of the shock. Beginning with a weak shock, I will build it up until it is as strong as you want to take it. Let me know by calling ont when it is strong enough. All I want is to have it intense enough to make you lift your fiuger from the electrode without thinking much about it."

E then went into the experimental room and obtained the thresholds for two different tones. The intensity of the shock was adjusted to the *S*'s toleration. This intensity level was used throughout the experiment unless the latent times to the shock alone began to increase much beyond the average time of the first 10 responses. If this occurred, the shock was increased to the point that the latent times were reduced appropriately.

Following these various tests, the standard procedure was then begun. This procedure consisted of:

A. Three presentations of the tone alone. The intensity of the tone was set at 50 decibels above the threshold value, and the particular tone used was of the frequency that would be employed in the final test. If any *S*s responded to the tone alone at this time, they were discarded from the experimental group. Only one *S* had to be eliminated from the group for this reason.
B. Three shocks alone.
C. One hundred thirty paired stimulations. The time intervals between these stimulations varied from 5 to 35 sec. Four subjects out of 63 did not show any conditioned responses as measured by anticipatory reactions during this training, and these *S*s were not continued on the experiment.
D. *E* entered the *S*'s room, and told him: "Now, I want to turn your hand over so that the same finger is on the electrode, but your palm is up." The hand was then turned over, and the recording contacts adjusted to the new position. If *S* asked any questions at this time, *E* replied that he would answer them later.
E. Thirty sec. after *E* returned to the experimental room, he began to present the tone alone. This was presented for 10 trials. Time intervals between presentation varied, and were the same for all *S*s.

The *S*s in the three experimental groups were conditioned or tested to tones with a frequency of 256, 512, or 1024 cycles per sec. Group I was conditioned and tested to the same tone, there being five individuals conditioned to each of the tones. The *S*s in Group II were conditioned to one tone and tested to another differing from it by one octave. Half of the *S*s were conditioned to the lower or the middle tones, and tested to the tone just higher, and the other half were conditioned to the highest or middle tone and tested to the tone just lower. The *S*s in Group II were tested to a tone differing by two octaves from the training tone. Half of them were conditioned to the highest and tested to the lowest tone, and the reverse procedure was employed for the other half. There were 16 *S*s each in Groups II and III.

II. Control Procedure

The Control Group composed of 12 *S*s was treated to the typical pseudo-conditioning procedure. They were tested to the tone and shock in the same manner as the experimental groups, but instead of being given 130 paired stimulations, they were given 130 shocks alone. They were then tested to the tone alone with the hand turned over in precisely the same manner as the experimental groups.

The directions given to this group at the beginning of the experiment differed, of course, from those given to the experimental *S*s. The directions were:

"If you don't mind, I will tell you nothing much about the experiment until it is over, then I will tell you everything you may want to know.

"During the experiment your hand will be strapped to this board with your middle finger resting on this electrode, and the other electrode fastened to your wrist. You will

receive a shock which will pass from one electrode to the other. You can break the shock by lifting your finger from the electrode. During the experiment you will be given a series of these shocks."

Following this the same information about obtaining the thresholds for the tones and the desired strength of shock was given.

Results and Discussion

A. *Response Generalization.*—Transference of the form of the response from extension to flexion was evident in all the experimental groups. The number of *S*s who failed to show any response when the hand was turned over was 2 in Group I, 5 in Group II, and 6 in Group III. Three *S*s in Group I made extension responses when the hand was turned over. One of these *S*s made 5 extension responses before extinction, and the other *S*s made 7 and 3 extension responses, and then changed the form of the response to flexion. No *S*s in the other two groups made extension responses.

B. *Conditioning vs. Pseudo-conditioning.*—The results for the three experimental groups and the control group are given in Table I.

TABLE I

The Mean Number of Responses and the Variability of the Transferred Conditioned Response for the Experimental and Control Groups

Group	N	M	σ
Group I	15	5.87	3.66
Group II	16	3.69	3.45
Group III	16	4.19	4.33
Group C	12	.16	.37

In column one the various groups are identified, column two gives the number of *S*s in each group, column three indicates the mean number of responses, and column four gives the standard deviation of the distribution.

It can be readily seen from the table that the means of the experimental groups are considerably greater than the control mean. The difference between the control and each of the experimental means is significant at the one percent level of confidence.

These results are concordant with those obtained in a previous study by the writer (**12**), and they indicate that the transference of the response to the new position cannot be completely accounted for by the occurrence of shock alone, but is primarily dependent upon the pairing of the tone and shock in the former position.

C. *Response Generalization During Stimulus Generalization.*—Generalization of the generalized response is clearly indicated in the data of the experiment. In all of the experimental groups, many of the

Ss gave conditioned responses to the tone alone in the new situation, whether or not they had been tested to the same tone, or to a tone one or two octaves different from the training tone. The data show some tendency for the same tone to be more effective in eliciting the transferred conditioned response than were the generalized tones, if direct comparison of the means is made. Treatment of the data by an analysis of variance, however, produces an F-ratio of less than one. Thus, there is no statistical evidence that any one of these stimuli are more effective than any of the others.

This result is probably to be expected on several counts. Humphreys (**5**) has shown that losses in the magnitude of the response during stimulus generalization are not great if the test tone bears an octave relationship to the training tone. Secondly, it will be recalled that the tonal stimulus was brief in duration, and had a sudden onset. This would result in a large number of similar component frequencies during the onset of each of the tones (**9**).

The results of the experiment militate against the narrow interpretation of conditioning previously referred to, for not only is the form of the response different from the one that was originally trained, but this generalized response may be evoked by other stimuli than those that were used in the initial training. Neither is the conditioned response in this situation stereotyped in form, nor is the varied form of the response uniquely tied to the original conditioning stimulus.

Summary

The present experiment was designed to test for the possibility of stimulus generalization of the generalized conditioned response. Three groups of subjects were conditioned to tonal stimuli. Shock served as the unconditioned stimulus, and finger extension was the conditioned response. The *Ss*' hands were then turned over and the tone alone was sounded. For one group the same tone was used, for another the test tone differed by one octave from the training tone, and for the third group a two-octave difference was employed.

A large number of *Ss* in all groups responded to the tone alone in the new situation, the nature of the response being characteristically flexion rather than extension. No significant difference in the frequency of the response existed in the three groups.

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Bibliography

1. Bass, M. J., & Hull, C. L. The irradiation of a tactile conditioned reflex in man. *J. comp. Psychol.*, 1934, **17**, 47–65.
2. Finch, G. Hunger as a determinant of conditional and unconditional salivary response magnitude. *Amer. J. Physiol.*, 1938, **123**, 379–382.

3. HILGARD, E. R., & MARQUIS, D. G. *Conditioning and learning.* New York: D. Appleton-Century Co., 1940.
4. HOVLAND, C. I. The generalization of conditioned responses. I. The sensory generalization of conditioned responses with varying frequencies of tone. *J. gen. Psychol.*, 1937, **17**, 125–148.
5. HUMPHREYS, L. G. Generalization as a function of the method of reinforcement. *J. exp. Psychol.*, 1939, **25**, 361–372.
6. LIDDELL, H. S., JAMES, W. T., & ANDERSON, O. D. The comparative physiology of the conditioned motor reflex based on experiments with the pig, dog, sheep, goat, and rabbit. *Comp. Psychol. Monogr.*, 1934, **11**, No. 1.
7. PAVLOV, I. P. *Conditioned reflexes.* London: Oxford University Press, 1927.
8. RAZRAN, G. H. S. Studies in configural conditioning. VII. Ratios and elements in salivary conditioning to various musical intervals. *Psychol. Rec.*, 1938, **2**, 370–376.
9. STEVENS, S. S., & DAVIS, H. *Hearing.* New York: John Wiley & Sons, 1938.
10. WALKER, K. C. The effect of a discriminative stimulus transferred to a previously unassociated response. *J. exp. Psychol.*, 1942, **31**, 312–321.
11. WENGER, M. A. An investigation of conditioned responses in human infants. *Univ. Ia. Stud. Child Welf.*, 1936, **12**, 9–90.
12. WICKENS, D. D. The transference of conditioned excitation and conditioned inhibition from one muscle group to the antagonistic muscle group. *J. exp. Psychol.*, 1938, **22**, 101–123.
13. WICKENS, D. D. The simultaneous transfer of conditioned excitation and conditioned inhibition. *J. exp. Psychol.*, 1939, **24**, 332–338.
14. ZENER, K., & MCCURDY, H. G. Analysis of motivational factors in conditioned behavior: I. The differential effect of changes in hunger upon conditioned, unconditioned, and spontaneous salivary conditioning. *J. Psychol.*, 1939, **8**, 321–350.

THE FACTOR OF ATTITUDE IN ASSOCIATIVE MEMORY *

BY LEO POSTMAN AND GARDNER MURPHY

College of the City of New York

Introduction

In many of the traditional studies of memory, as exemplified notably by the work of Ebbinghaus, an attempt was made to isolate the memory function per se by eliminating to the greatest possible extent such factors as meanings, associations, and affective values. These studies were motivated by the attempt to understand the organism by taking its constituent acts one by one, the total behavior of the organism being regarded as the summation of the activities of its parts. Meanings, associations, and affective values were thought to be superimposed on more basic and primitive memory 'bonds,' the formation of which could be studied with the aid of nonsense material. With the increasing emphasis in modern psychology on functional wholes, as represented for instance by the Gestalt and organismic approaches, such an approach to memory could not remain unchallenged.

An important contribution to a reconsideration of the subject was made by Bartlett in his book on *Remembering* (1). Bartlett criticizes the Ebbinghaus approach not only because it constitutes an artificial abstraction from the actual life situations in which human beings recall and recognize previous experiences, but also because of the practical impossibility of holding the factor of meaning constant, since each individual will interpret the material in his own way and attempt to assimilate it in a manner which is peculiarly his own. However chaotic or unstructured a stimulus may be, the resulting experience will have structure and organization, the subjective or autistic factor assuming increasing importance the less structured the stimulus situation becomes. This was demonstrated experimentally by Sherif (2) with the aid of the autokinetic effect. We may think, therefore, in terms of a dynamic interrelationship between the structural attributes of the stimulus situations and the organized perceptual dispositions of the organism, the end-result always being an ordered, meaningful perception in which, as Goldstein would say, the organism "comes to terms with the environment." In the experimental approach to memory it therefore becomes necessary not to

* An honors study conducted by Leo Postman under the direction of Gardner Murphy.

eliminate the structural attributes of the material to be memorized, but rather to vary them in such a manner as to make it possible to obtain a quantitative measure of their effects.

Most of the investigations along these lines have attempted to introduce such variation in one dimension only, viz., that of hedonic tone. The differential rate of retention and recall is studied for material previously classified as pleasant and unpleasant. Although the general trend of the data seems to favor the recall of pleasant material as contrasted with unpleasant and indifferent material, the evidence is still conflicting. As Meltzer (3), in a comprehensive survey of the field, points out, the source of such conflict must be sought not only in frequently faulty experimental procedure, but also in the inadequacy of the pleasantness-unpleasantness dichotomy. Thinking, as above, in terms of the structural quality of the stimulus situation, pleasantness or unpleasantness is only one of the dimensions that are pertinent. Such factors as logical compatibility, or autistic interpretation in relation to the subject's wish for security, also enter. It thus becomes necessary to define the value of the stimulus situation for the subject in a more comprehensive way, viz., in terms of his *attitude*, which, operationally defined, would go beyond the pleasantness-unpleasantness dichotomy. An important contribution along these lines was made by Seeleman (4), who demonstrated the effect of attitude toward the Negro on ability to recognize pictures of members of that race which had been presented earlier.

Watson and Hartmann (5) studied the difference in recall of atheistic and theistic material by subjects with atheistic and theistic attitudes. Material in harmony with a subject's attitude was recalled more effectively. Similar results were obtained for pro-Communist and anti-Communist material by Levine and Murphy (6), who also report that the speed of forgetting varies with the subject's attitude. In a recent survey of the field, Rapaport pointed out that "a new theory of learning will have to embrace not only the problems of rote learning . . . but also the problem of memory functioning in every day thought processes" (7, p. 241).

Thinking in terms of attitude, the question suggests itself to what extent a person's attitude toward material connected with the war will be reflected in his memory for such material. The subject's life history, the cumulative effects of all the social conditionings to which he has been subjected, will enter into his evaluation of the stimulus, and into his recall of it. To explore the relationship between the attitude toward the war and memory for material connected with it the present study was undertaken.

Subjects and Procedure

The *Ss* of the experiment were 28 students of the eighth grade at the Hunter College Elementary School in New York City. Children were used as subjects because it was believed (in agreement with K. Lewin) that the tendencies under consideration might be more clearly expressed in young *Ss*, who are perhaps prone to more uncompromising attitudes and tend less to repress or mask their emotional reactions. The *Ss* used constituted a fairly homogeneous group: the age differences were minimal, all the students being from 12 to 13 years of age, and since the school selects bright pupils, the intelligence quotients clustered around 120.

The procedure comprised: (1) a paper-and-pencil attitude schedule administered to the group as a whole, and (2) individual sessions with each of the *Ss*, during which he or she was required to perform a memory task.

The attitude schedule contained 48 items designed to ascertain the *S*'s attitude toward (*a*) the United Nations, (*b*) the Axis powers. The *S* indicated his reaction to the statements, each of which was of a value-judgment type, along a five-point scale. Thus, to the statement, "In spite of the crimes of their leaders the German people are a kindly people," the *S* could respond by checking one of the following five items, 'strongly agree,' 'agree,' 'undecided,' 'disagree,' 'strongly disagree.'

Other examples of statements in the questionnaire are as follows:

England's victory is important for the future of the world.
We should hate all Fascists.
On the whole, the Chinese are decent people.
Hitler is the most wicked man in the world.
The democracies are innocent of the sufferings caused by this war.

Following the practice of students of attitude, differently worded questions pertaining to the same attitude were distributed throughout the questionnaire to provide a test for internal consistency; the same attitude would sometimes require a positive, sometimes a negative response. To test for reliability, the questionnaire was first administered to a preliminary group. The reliabilities (by the split-half method and the Spearman-Brown formula) proved to be:

Attitude toward the United Nations.....75
Attitude toward the Axis Nations.....96

The corresponding results obtained from the experimental group were:

Attitude toward the United Nations.....83
Attitude toward the Axis Nations.....96

The reliability of the questionnaires was therefore sufficiently high to make it possible to proceed to the second part of the experiment.

From the statements of the attitude schedule, word-pairs representing various degrees of 'compatibility,' as empirically determined for each *S*, were then lifted out, to be used in a paired-associate memory task. The words were equated, as far as was possible (without sacrificing meaningful relationships) for frequency of usage by reference to Thorndike's *Teacher's word book* (8), so that only a minimum of differences in recall could be ascribed to varying difficulty of the words. Thus, if an *S* had indicated his strong agreement to the statement that the German people are a kindly people, the word-pair 'German—kindly' was judged to have a compatibility value of +2, while if he had disagreed strongly, a value of −2 was given, and so along the five-point scale ranging from +2 to −2. Fifteen such pairs were then learned by the *S*, using the paired-associate procedure, along with 15 control pairs of randomly selected words, such as 'path—butter,' 'school—grocery,' etc. In this manner the *Ss* acted as controls on themselves.

The test pairs used were as follows: England—glorious, German—kindly, democracies—innocent, Chinese—decent, Axis—dangerous, Nazis—honest, Italy—sincere, Hitler—splendid, Russians—approve, Fascist—hero, Stalin—resign, Japanese—friendship, Mussolini—worthy, Churchill—excellent, Allies—progress, British—friends, Axis—peaceful, Nazi—cruel.

The control pairs used were as follows: invite—peach, star—fourth, crush—dark, railroad—secret, master—steep, sailor—allow, cabbage—doll, roof—guide, mischief—gift, path—butter, school—grocery, ride—occasion, prayer—thirty, soldier—stone, escape—overcoat, insect—average.

The entire list—test pairs and control pairs—was presented to the *S*, and he or she read them aloud to the beat of a metronome. In testing for recall, the left-hand words in each pair were exposed on cards at three-second intervals, the *S* was given three seconds to answer, and he was prompted if he failed to respond or gave an incorrect response. The exposure order of the cards was completely randomized. Time was kept by means of a metronome. The *S*s were kept in ignorance of the purpose of the experiment, and in most cases considered it a simple memory test. Twelve series of cards were exposed to each *S*, which in some cases resulted in overlearning. The number of trials was kept constant in order to obtain comparable data for the entire group.

Results

The results obtained may be considered under two headings: (1) the learning curves obtained for each of the five categories of test-pairs, i.e., −2, −1, 0, +1, +2 (in terms of the individual responses on the attitude schedule), comparing the learning curves for the test-pairs with those for the control-pairs of unrelated words; (2) a statistical analysis of the results obtained for each of the 12 successive trials.

Figure 1 shows the learning curves for the five categories of test-pairs, with the trials plotted along the abscissa and the percent correctly recalled along the ordinate. It shows clearly that the pairs in the various categories were recalled with varying degrees of success at different points on the curve. Pairs at either extreme of the scale—relationships completely endorsed and connections completely rejected—were retained in preference to the other categories. Of these, the +2 pairs were retained in preference to the −2 pairs. The +1 pairs were retained in preference to the −1 pairs, with the 0 pairs overlapping both the +1 and −1 pairs. Of the two factors operating, *extremeness* of compatibility or incompatibility, and *sheer degree of acceptability of the relationship* expressed in the pair, the former was, therefore, the more effective one: a −2 pair would be retained, on the whole before a +1 pair. Of pairs equidistant from the zero point, the pair embodying the more acceptable relationship was preferred in retention. Although the curve for 0 pairs, embodying relationships toward which the *S* professed indifference, intersects with both the +1 and the −1 curves, it tends, on the whole, to coincide more with the −1 curve.

Figure 2 shows the learning curves for the test pairs, i.e., all five categories combined, as compared with the curve for the control pairs. It clearly shows what had been evident to *E* during practically every individual session: the control pairs, i.e., the incongruous pairs, were retained in preference to any of the test pairs. This fact raises an important problem over and above the question which the experiment was designed to test (*cf.* Discussion).

For a better understanding of the curves, a statistical analysis of the results obtained for each of the 12 successive trials was made. Chi-square tests were applied to the distribution of pairs correctly

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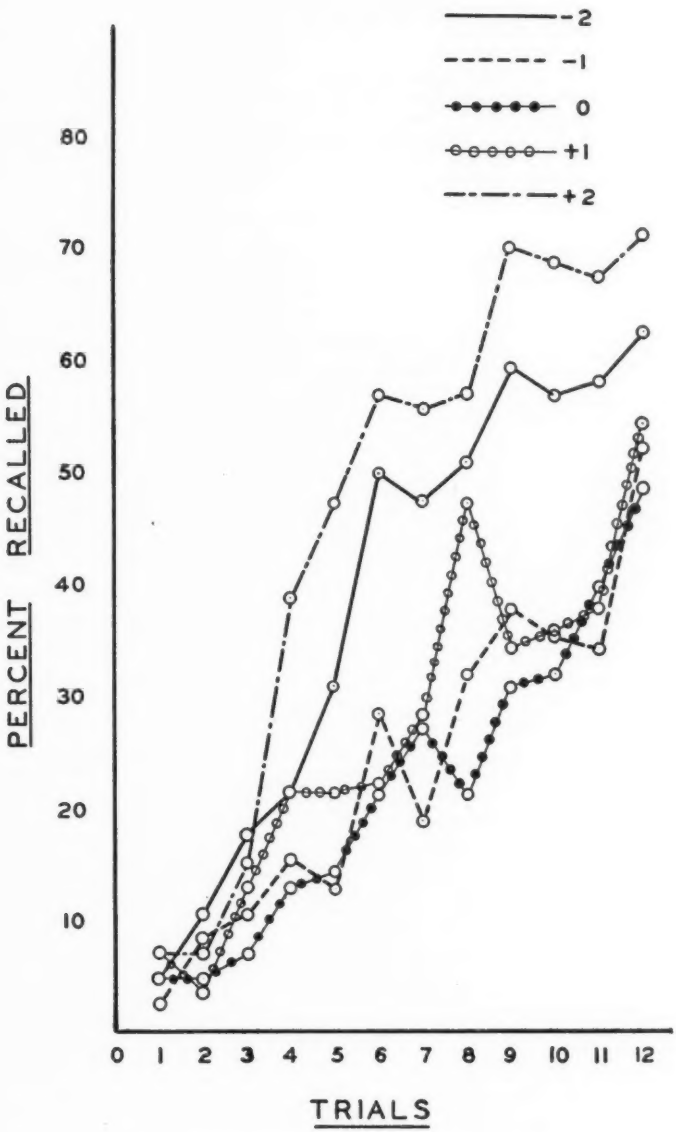

FIG. 1. Percent recalled in each category on each trial

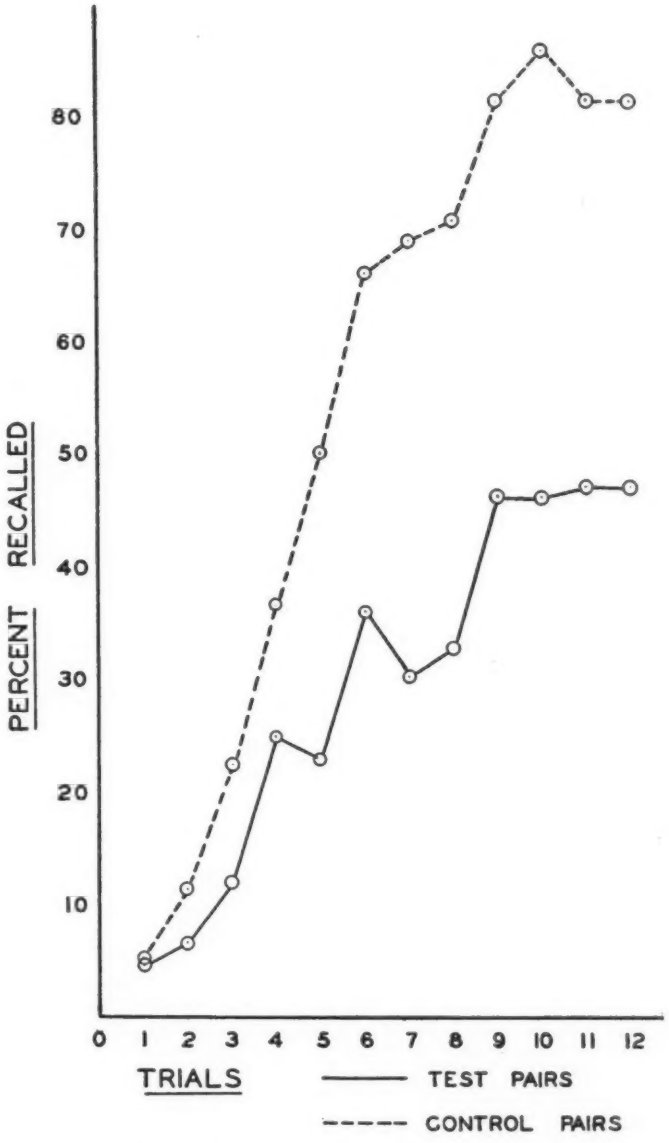

FIG. 2. Percent of test pairs and control pairs recalled on each trial

recalled on each trial, to test the hypothesis of even distribution due to the operation of chance. Table I shows chi-square and P-values obtained for each of the trials.

P-values indicated that, in differentiating between the five categories, the operation of chance factors is not contradicted for the first trials. The number of correct responses on these trials was too small to allow for any definite differential rate of retention to become evident. From the 4th to the 11th trial the low P-values clearly showed that the distribution should not be ascribed to chance. On the 12th trial P rose again above the level of significance. Over-learning of the preferred categories made it possible for the non-preferred pairs to reach the same level of retention as the preferred pairs, several *Ss* obtaining a perfect score on the 12th trial, which made any further differentiation among the various categories impossible. The significant differences in the distribution of correct responses are thus limited to the 4th to 11th trials. The very low probability values may be partly due to the fact that the tests were made for cumulative frequency, which, however, seemed the most logical procedure.

TABLE I

χ^2 AND P-VALUES FOR CHANCE DISTRIBUTION FOR EACH TRIAL

Trial	χ^2	*P*
1	1.5	.80
2	3.5	.50
3	4.1	.46
4	40.1	<.01
5	26.8	<.01
6	23.6	<.01
7	18.8	<.01
8	18.0	<.01
9	15.7	<.01
10	24.0	<.01
11	18.3	.02
12	4.5	.48

With the chance hypothesis eliminated for the 4th to 11th trials, the significance of the differences among the various categories of compatibility was ascertained for each of these trials. The standard errors of the difference between percentages, and then the critical ratios, were obtained for each of the 10 possible combinations for each of the trials. Table II shows the percentage of correct responses on each trial. The critical ratios of the differences between these percentages confirmed the general trend evident in the curves of Fig. 1. Critical ratios tend consistently to be high between extremes and non-extremes, e.g., between +2 and −1, or −2 and +1, independently of their acceptable or unacceptable character, and less high between percentages for items equidistant from the zero point of the scale, e.g., between +2 and −2, or +1 and −1.

TABLE II

PERCENT CORRECT IN EACH CATEGORY ON EACH TRIAL

Trial	Category				
	−2	−1	0	+1	+2
1	4.8	2.4	4.8	7.1	7.1
2	10.7	8.3	4.8	3.6	7.1
3	17.8	10.7	7.1	13.0	15.4
4	21.4	15.4	13.0	21.4	39.1
5	30.4	13.0	14.3	21.4	47.6
6	50.0	28.5	21.4	22.3	57.1
7	47.7	19.0	27.4	28.5	55.9
8	51.1	32.1	21.4	47.6	57.1
9	59.5	38.0	30.9	34.5	70.2
10	57.1	35.7	32.1	36.1	69.0
11	58.3	34.5	40.0	38.1	67.8
12	62.8	52.3	40.0	54.7	71.4

A similar procedure was followed with regard to the differences between test pairs and control pairs. Table III shows the percentages of test pairs and control pairs recalled on each of the 12 trials. From the third trial on, the critical ratios indicate significant differences between the percentages of test pairs and control pairs recalled, all these differences being in favor of the control pairs composed of unrelated words, as shown in Fig. 2.

TABLE III

PERCENT OF TEST PAIRS AND CONTROL PAIRS RECALLED ON EACH TRIAL, WITH THE CRITICAL RATIOS, TO SHOW THE SIGNIFICANCE OF THE DIFFERENCES

Trial No.	% Correct Test Pairs	% Correct Control Pairs	Critical Ratio (D/σ_D)
1	4.5	5.2	.46
2	6.6	11.6	2.5
3	12.1	22.4	4.3
4	25.4	36.9	3.4
5	23.1	50.1	8.5
6	36.2	66.2	9.1
7	30.2	69.3	12.6
8	33.1	70.9	12.2
9	46.4	81.8	11.8
10	46.3	86.1	10.7
11	47.6	81.9	11.3
12	47.6	81.8	11.3

DISCUSSION AND CONCLUSIONS

Three significant trends seem to be indicated by the results of the experiment; (1) associations with regard to which the *S* has an emphatic, extreme attitude are formed more speedily than associations toward which the attitude is less emphatic; (2) to a much smaller

degree there obtains a similar difference in favor of acceptable, as against unacceptable, associations; (3) when confronted with both meaningful associations bearing on material of a political nature and incongruous pairs of words, the *S*s of this experiment consistently did better with the incongruous material. Confronted with such facts, an explanation in terms of synaptic bonds will have little value. It cannot be argued that the incongruous combinations have occurred more frequently, or more recently, or have been of a more satisfying nature. In all probability they occurred seldom, if at all, in most cases. All the words to be learned fell into the same vocabulary range so that they presented equal difficulty as far as the *S*s' verbal ability is concerned.

We must seek an explanation, therefore, in terms of the meaning of the situation to the *S*, in terms of its structure as related to his own frame of reference. A +2 pair, an association toward which the *S* has an emphatically positive attitude, represents a well-structured stimulus, a stimulus which may easily be located with regard to his political and social frames of reference. Such associations represent a 'good Gestalt,' and closure can occur. A −2 pair, on the other hand, a pair embodying a relationship with which the *S* strongly disagrees, is in such complete contradiction to the interiorized values and norms which constitute the *S*'s frame of reference that it acquires a high negative value, especially if the association may also involve a certain verbal threat to the *S*'s sense of security; a pair like 'Fascist—hero' may challenge the child's accepted beliefs and thus his sense of security. To the extent that the other categories have these qualities to a smaller degree with regard to the *S*'s frame of reference, they are retained with less success.

With regard to the preferred retention of incongruous pairs, we may again attempt an explanation in terms of the *S*'s frame of reference. Genetic studies of children have shown that the child tends to interpret the environment in terms of a frame of reference which is essentially egocentric. The emancipation from what Piaget has termed the child's 'realism' is slow. Now, the control pairs, although embodying incongruous associations, are composed of concrete words. Words like 'butter,' 'school,' 'grocery,' 'overcoat,' 'peach' are words from the child's own world, and in terms of an egocentric frame of reference are more important than abstract relationships such as 'German—kindly.' And because they are so much more important, the stimulus can so much more easily be structured in terms of the child's experiences and wishes. Because the child's view of the world is still largely ego-determined, such material as fits into the egocentric structure is likely to be better retained. The concept of 'egocentricism' is here used tentatively

without necessarily implying Piaget's meaning of the word. It is necessary to consider the possibility of a 'withdrawal' of the subjects from the emotionally charged material, an interpretation suggested by Rorschach data showing the presence of 'emotional constriction' in children of the pre-adolescent age group. In a recent study, Hertzman and Margulies (9) said that "the excess of movement over color was greater in the younger group than in the older, pointing to a more extensive introvertive picture in the younger group." It therefore becomes necessary to explore the role played by both these factors, namely egocentricism and emotional constriction, which need not be mutually exclusive. Experiments are needed (1) testing the differential recall value of 'neutral' and emotionally tinged material at different age levels including adults,[1] and (2) using with children of various age levels 'neutral' material and critical emotional material from the children's own 'psychological life space.'

Summary

The problem of this study was to ascertain to what extent an *S*'s attitude toward material connected with the war will influence his memory for such material. An attitude schedule testing attitude toward the United Nations and the Axis powers was administered to a group of eighth grade students. From the schedule, which had been scored on a five-point scale, word-pairs embodying various degrees of compatibility (empirically determined for each child) were constructed, and given to the *S*s as a paired-associates test, together with an equal number of control pairs consisting of randomly related words. The group data for 12 series of presentations indicate: (1) that pairs located at either extreme of the attitude scale are retained with greater success than pairs nearer to the zero point of the scale; (2) that acceptable pairs are retained better than unacceptable pairs, the difference in this case being less striking than the difference between extremes and non-extremes; (3) that the control (incongruous) pairs are retained significantly better than the pairs constituting the test series, i.e., meaningful pairs. An interpretation of the results in terms of the structural qualities of the stimulus materials was attempted.

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References

1. Bartlett, F. C. *Remembering.* Cambridge: Cambridge Univ. Press, 1932.
2. Sherif, M. *The psychology of social norms.* New York: Harper & Bros., 1936.

[1] A preliminary group memory experiment using similar material with high school seniors showed a tendency for the relative recall value of 'neutral' and emotional material to be the reverse of that reported for the younger children.

3. MELTZER, H. Present status of experimental studies on the relationship of feeling tone to memory. *Psychol. Rev.*, 1936, **37**, 124–139.
4. SEELEMAN, V. The influence of attitude upon the remembering of pictorial material. Arch. Psychol., 1940, **36**, No. 258.
5. WATSON, W. S., & HARTMANN, G. W. The rigidity of a basic attitudinal frame. *J. abn. soc. Psychol.*, 1939, **34**, 312–335.
6. LEVINE, J., & MURPHY, G. (in press)
7. RAPAPORT, D. Emotions and memory. *Psychol. Rev.*, 1943, **50**, 234–243.
8. THORNDIKE, E. L. *The teacher's word book.* New York: Teachers College, 1921.
9. HERTZMAN, M., & MARGULIES, H. Developmental changes as reflected in Rorschach test responses. *J. genet. Psychol.*, 1943, **62**, 189–215.

THE EFFECT OF DELAY UPON THE DUPLICATION OF SHORT TEMPORAL INTERVALS *

BY WALTER J. KOWALSKI

Fordham University

Psychologists have devoted much energy to investigations whose chief aim was to determine the conditions that influence our experience of time. The principal methods utilized in the study of time perception are the methods of comparison, estimation and duplication. The method of duplication, in which the subject reproduces the duration of a time interval, is possibly more accurate and more flexible than either of the other two methods.

Many of the studies, as reported in the journals, deal with a duration of time bounded by taps or clicks. These limiting sounds, however, are detrimental to the accuracy of the results, because subjects tend to incorporate into the time interval these limiting sounds, which themselves take an appreciable length of time.

The prime objective of this investigation is to determine the influence of varying delay intervals upon the duplication of short temporal intervals. The delay interval is defined as the period of time that elapses between the end of the stimulus and the beginning of the response. It is proposed to determine whether any trend can be discerned and attributed to the varying lengths of the delay interval, i.e., what kind of relationship exists between the delay interval and the stimulus durations.

Herbert Woodrow (**3**), one of several outstanding investigators in the field of time perception, determined from introspective reports that only time intervals having a duration of more than 1.5 sec. have a definite experience of duration. Furthermore, he reports that "so far as could be determined, data concerning the delay of the subjects in initiating their reproductions have no significant bearing upon the accuracy of the subjects' performances nor upon the nature of the individual differences" (**3**, p. 496). It was with the object of exploring in some detail this finding of Woodrow's that the present investigation was undertaken.

In a study of time perception the method or apparatus used to present and to reproduce temporal durations is always an important problem. Early investigators were handicapped by the lack of an

* This research was done in the Fordham Psychological Laboratory. Acknowledgment is made to Dr. B. R. Philip for suggesting the problem.

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adequate instrument for controlling and measuring temporal intervals. For this study an apparatus was designed not only to control accurately the stimulus duration, but also to make it possible for the subject to duplicate this duration in the same manner as it was presented by the experimenter.

Apparatus

The materials used in this experiment are an interval timer, variac, voltmeter, two chronoscopes, double-pole double throw switch, neon lamp and a buzzer.

The interval timer was designed by Dr. B. R. Philip, of the Psychology Department of Fordham University, and collaborators, Messrs. Reintjes and Weil, of the Electronic Engineering Laboratory of Manhattan College (*vide* 2). This interval timer is an apparatus designed primarily for experiments on time perception. Fig. 1 presents a diagram of the apparatus as used in this study.

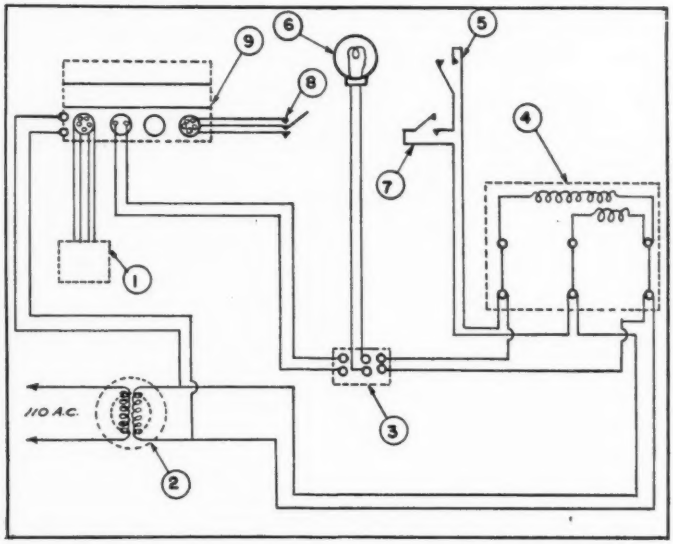

Fig. 1. Diagram of interval timer. 1. *E*'s Clock. 2. Variac. 3. 2-Pole, 2-throw switch. 4. *S*'s clock (rear). 5. *E*'s reaction key. 6. Light (neon). 7. *S*'s reaction key. 8. Interval key. 9. Timer (back).

The interval timer automatically regulates the duration of each stimulus light exposure according to a pre-determined plan. The variac is used to regulate the voltage to the interval timer in order to keep the stimulus time constant. The voltage is checked by frequent voltmeter readings.

Two chronoscopes, calibrated in hundredths of a second, register the duration of the stimulus and of the response. The *S*'s clock is connected to the *S*'s key. The double-throw switch permits *E* to connect the neon lamp, alternately, to the interval timer while sending the stimulus, and to the *S*'s key while receiving the response.

The period of time used as the stimulus duration is a light exposure produced by a neon lamp and controlled by the interval timer. A neon lamp lit for a definite period of time yields, for

experimental purposes, a satisfactory approximation to a pure interval of time, for the problem of bounding a temporal interval by clicks or by some other definite stimuli is attenuated. The neon lamp was used in preference to the ordinary mazda lamp because, owing to the hue and mild intensity of the neon lamp, the effect of after-imagery is minimized. Furthermore, in a neon lamp there is no perceptible delay in attaining brilliance or in its return to zero (1). In an investigation such as this, where the succession of stimuli is fairly rapid, an ordinary lamp would result in confusing the actual duration of the light with the apparent duration of the light. Greater persistence of vision is increased by greater intensity of light; thus a neon lamp, having much lower intensity than the ordinary mazda lamp, would minimize this persistence.

The buzzer device, used as a signal for the subject, is the usual buzzer device in series with a bell-ringing transformer and a telegraph key.

Procedure

The *S* was seated in a moderately lighted room, so that the neon lamp could be readily perceived when lit. Before him there was a telegraph key, used to duplicate the temporal exposure of the neon lamp. The lamp itself was placed against a gray background, in order to secure optimum conditions of contrast. The *S* was instructed to duplicate as accurately as possible the duration of the exposed light. Also, in order to control as much as possible the mental activity of the *S*, each *S* was instructed to perform a prescribed task, whenever he was not engaged either in attending to the stimulus exposure, or in duplicating it. The *S* was instructed to color a geometrical design, prepared by the author, in any way he pleased by using red and blue pencils provided for this purpose.

E was seated in another room, from which he presented the stimulus durations, and in which he recorded the readings. A buzzer signal warned *S* that the stimulus duration was to be given. Then to give the stimulus, *E* placed the double-throw switch in a sending position, adjusted the desired tap on the interval timer, and depressed the key which lit the neon lamp in the *S*'s room for the determined length of time. The duration of this stimulus light exposure was recorded in *E*'s room on the chronoscope in series with the interval timer. *E* then quickly threw the double throw switch from a sending to a receiving position. As quickly as possible, at the completion of the stimulus duration, *E* started the stop-watch, used to measure the delay interval. After the desired period of time elapsed, *E* signaled *S* to begin the duplication. *S* then depressed his key, lighting the neon lamp. The key was held down until *S* felt that he had duplicated the stimulus exposure; then he released the key. *S*'s duplicated exposure was registered on the second chronoscope. *E* recorded the readings on both chronoscopes. The voltage was checked both at the beginning of each session and during the rest period occurring midway in the session.

E then adjusted the interval timer to control automatically the next time exposure. With the relay switch in a sending position, *E* again gave the buzzer signal and depressed the key which lit the lamp for the next duplication.

The instructions given to each *S* were as follows:

"The purpose of this experiment is to find out how accurately you can duplicate time. I will flash a light before you, and you will try to make your flash equal in length to mine. A buzzer sound will be a signal for you to get ready, so that you can pay attention to the flash of light.

"When the light goes out, start coloring the design before you with red and blue pencil. You may color the design in any way you please. The sample shows one way of coloring the design.

"When I give you the buzzer signal again, stop coloring the design and press down on the key before you; this will light the lamp. Keep the key down until you feel that the light is on as long as it was when I put it on, then release the key. After you release the key, continue coloring the design. This procedure will be the same throughout the experiment. Do not count in any way. Do your best at all times."

The stimulus durations used in this experiment were seven short temporal durations of approximately 0.48, 0.92, 1.90, 4.10, 6.25, 8.85 and 16.20 sec. Seven delay intervals were used, namely, 2.5, 5.0, 10.0, 15.0, 20.0, 25.0, and 30.0 sec.

In order to eliminate as much as possible the influence of any stimulus duration or any delay interval in a series upon the duplication of the succeeding duration, both the stimulus durations and the delay intervals were randomized in accordance with a Graeco-Latin square arrangement. This arrangement enabled the author to present the stimuli and the delay intervals to the *S*

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in such a way that within a series every stimulus duration occurred only once in combination with each delay interval.

The *Ss* of this experiment were 30 high school students of Fordham Preparatory school. All of these students were naive *Ss* for this experiment, as none of them had taken part in any previous psychological experiment. The average age of this group was 15.5 years.

The experimental procedure was so arranged that a complete series of judgments could be obtained from each *S*, while they were still naive. In order to shorten the fore-practice, each *S* was carefully instructed in the experimental procedure. A brief practice period, consisting of five judgments, was given before each session.

The *Ss* were tested during two sessions, which occurred on different days. A session consisted of two series. During each series 49 judgments were secured from an *S* i.e., 98 judgments per session. The judgments obtained during two sessions totaled 196 per *S*. In all, a total of 5880 judgments were secured from 30 *Ss*.

A rest period of three min. was given at the end of the first series of each session. The experimental time for each session approximated 45 min.

Results

The data for each *S* were recorded on prepared sheets, on which both the stimulus durations and the delay intervals were tabulated in accordance with the plan for randomization. The data thus gathered were classified for each *S* according to stimulus durations and delay intervals. Thus there were seven sets of S (stimulus) and R (response) data for each *S*.

Since the stimulus durations varied to some degree due to voltage fluctuations and the variability of the chronoscopes, a standard deviation was determined for each of the seven positions on the interval timer. Table I presents the mean, sigma and the coefficient

TABLE I

Mean, Sigma and Coefficient of Variability for Distributions of Stimulus Durations

Stimulus Duration	Mean	Sigma Dist.	Coefficient of Variation
0.48	0.483	.0096	2.0
0.92	0.926	.0157	1.7
1.90	1.904	.0305	1.6
4.10	4.151	.0603	1.5
6.25	6.253	.0814	1.3
8.85	8.909	.1024	1.1
16.20	16.233	.1479	0.9

of variation $\left(\frac{100\sigma_{\text{dist.}}}{M}\right)$ for each of the seven distributions of stimulus durations. The stimulus duration that appeared most frequently was taken as the standard duration. The *S*'s response was then corrected by the percent amount that each stimulus duration varied from this standard. The formula used for making this correction is $Rc = \frac{St}{S} \times R$ (Rc = corrected response; R = uncorrected response; St = standard time interval; S = stimulus time interval).

This correction enabled the author to treat all duplications of intervals from the same tap on the interval timer as responses to a standard stimulus interval. The corrected responses of all *Ss* were then pooled and distributions were made. For each of the seven stimulus durations there were seven distributions, one for each delay interval. The medians were then computed for each of the 49 distributions. Medians were used as the measure of central tendency, because in several instances the *Ss* made extreme duplications, which would have exerted too great an influence upon means and would have produced a distorted measure of central tendency. Table II

TABLE II

MEDIAN DUPLICATION TIMES IN SECONDS FOR ALL STIMULUS DURATIONS AT EACH DELAY INTERVAL

Stimulus Durations	Delay Intervals							Average Duplication
Seconds	2.5	5.0	10.0	15.0	20.0	25.0	30.0	
0.48	0.55	0.62	0.63	0.61	0.63	0.67	0.71	0.63
0.92	0.96	1.00	0.99	1.03	1.02	0.95	0.94	0.98
1.90	1.64	1.70	1.75	1.91	1.66	1.90	1.75	1.76
4.10	3.71	3.68	3.78	3.70	3.80	3.84	3.74	3.75
6.25	5.54	5.56	5.53	5.55	5.57	5.70	5.42	5.55
8.85	7.87	7.68	7.55	7.71	7.57	7.65	7.60	7.66
16.20	14.50	14.60	14.25	14.40	14.31	14.50	14.25	14.40

N.B. Medians are based upon four judgments from each of 30 *Ss*.

presents the median duplication times. An inspection of this table reveals that stimulus durations of 1.90, 4.10, 6.25, 8.85 and 16.20 sec. were consistently under-estimated for all delay intervals. However, when the duplications are considered with respect to the delay intervals, the differences are small. This suggests that the influence of delay intervals upon temporal duplications is not very significant.

Quartile measures of skewness of the corrected response distributions of all stimulus durations at each delay indicated that distributions of the shorter stimulus durations are for the most part positively skewed, whereas, those of the longer stimulus durations are negatively skewed.

PERCENT OF ESTIMATION AND ANALYSIS OF VARIANCE

The data were analyzed by analysis of variance in order to determine the significance of variations in the reproductions of stimulus durations with different delay intervals. By this method of analysis it was possible to determine whether the stimulus durations, or the delay intervals were the significant factors in the duplication of short intervals.

The analysis of variance was based on the data of Table III, which gives the percent of estimation of all stimulus durations (i.e., the relation between actual and estimated durations) at each delay interval. The results obtained by the analysis of variance are summarized in Table IV. From this table it is seen that to be significant

TABLE III

PERCENT OF ESTIMATION OF ALL STIMULUS DURATIONS AT EACH DELAY INTERVAL

Stimulus Durations	Delay Intervals							Average Percent
Seconds	2.5	5.0	10.0	15.0	20.0	25.0	30.0	
0.48	115	129	131	126	132	139	147	131.3
0.92	104	129	107	112	111	103	102	106.7
1.90	86	89	92	100	87	100	92	92.3
4.10	90	90	92	90	93	94	91	91.4
6.25	89	89	88	89	89	91	87	88.9
8.85	89	87	85	87	85	86	86	86.4
16.20	89	90	88	89	88	89	87	88.7
Average Percent	94.6	97.4	97.6	99.0	97.9	100.3	99.0	

N.B. Medians are based upon four judgments from each of 30 *Ss*.

TABLE IV

ANALYSIS OF VARIANCE

	Degrees of Freedom	Sum of Squares	Variance
Delays (b)	6	136.49	22.75
Stimuli (c)	6	10,943.92	1823.99
Interaction (b–c)	36	797.61	22.15
Duplications (a)	48	11,877.92	

F(stimuli) = 1823.99 ÷ 22.15 = 82.35
F(delays) = 22.75 ÷ 22.15 = 1.03

For 6 and 36 degrees of freedom, an F of 2.36 is at the 5 percent level, and an F of 3.35 is at the 1 percent level.

the F-value for the delay interval must exceed the values 2.36 for the 5 percent level and 3.35 for the 1 percent level. Therefore, it is evident that delay intervals (F = 1.03) are not significant factors in the duplication of short time intervals. Stimulus durations (F = 82.35) are without doubt the significant factors.

To analyze further the data obtained in this experiment, the mean percent of estimation was computed for each of the stimulus durations. All judgments, irrespective of the delay intervals, were combined and classified according to the stimulus durations. These

data are presented in Table III under the column headed "Average Percent," and are graphically illustrated in Fig. 2.

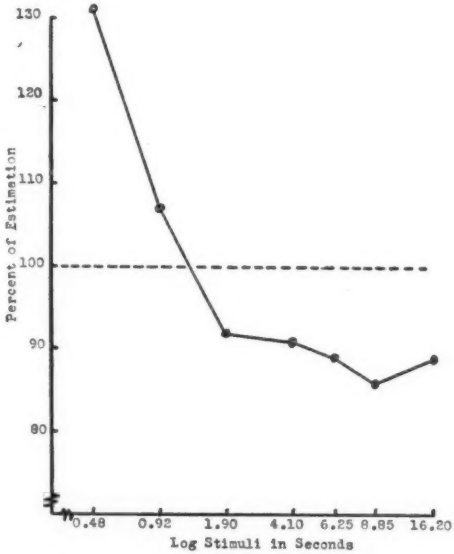

FIG. 2. Mean percent of estimation for all stimulus durations.

Similarly, all judgments, irrespective of the stimulus durations, were combined and classified according to the delay intervals. These data are also presented in the last row of Table III, and are illustrated by Fig. 3.

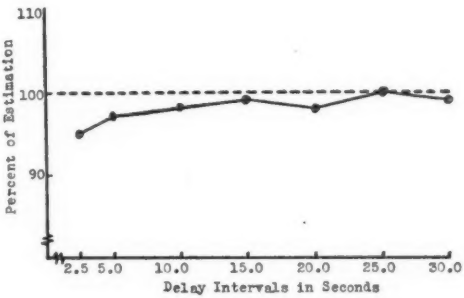

FIG. 3. Mean percent of estimation for all delay intervals.

Fig. 2 confirms the results previously reported, namely, that stimulus durations of 0.48 and 0.92 sec. are overestimated, whereas stimulus durations of 1.90, 4.10, 6.25, 8.85 and 16.20 sec. are under-

estimated. Here, however, an additional conclusion may be presented, namely, that as the stimulus duration increases, the mean percent of estimation of duplications regularly decreases. The only exception to this is the duplication of the longest stimulus duration, 16.20 sec., which shows a slight increase in the percent of estimation as compared with the previous stimulus duration.

Fig. 3 presents a composite curve showing the trend of duplications according to the delay intervals. The general tendency is to underestimate at all delay intervals, when these are averaged for all stimulus durations. Also, there is a slight tendency for the accuracy of duplications to increase with the increase of the delay interval. This slow rise in the curve, however, is small and the *t*-value of the difference between the smallest and the largest values is not significant ($t = 1.6$). This finding confirms a previously stated conclusion that delay intervals do not significantly influence the duplication of short temporal intervals.

Conclusions

This experiment suggests several conclusions that may be briefly stated as follows:

1. Stimulus durations of 0.48 and 0.92 sec. are consistently overestimated for all delay intervals.

2. Stimulus durations of 1.90, 4.10, 6.25, 8.85 and 16.20 sec. are consistently underestimated for all delay intervals.

3. Quartile measures of skewness indicate that distributions of shorter stimulus durations are positively skewed, whereas the distributions of the longer stimulus durations are negatively skewed.

4. Analysis of variance indicates that stimulus durations, rather than delay intervals, are the significant factors in overestimation or underestimation of time duplications.

5. Duplications averaged according to stimulus durations show that as the stimulus duration increases, the percent of estimation decreases.

6. Duplications averaged according to delay intervals indicate a tendency to underestimate at all delay intervals. There is a slight tendency for estimations to become more accurate with the increase in the length of delay intervals, but these differences are not significant.

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References

1. Kellogg, W. M., & Davis, R. C. The measurement of latent time of electric light bulbs. *Amer. J. Psychol.*, 1930, **42**, 300–301.
2. Philip, B. R., Reintjes, F., & Weil, R. T., Jr. An electronic interval timer. *J. exp. Psychol.*, 1943, **33**, 253–256.
3. Woodrow, H. The reproduction of temporal intervals. *J. exp. Psychol.*, 1930, **13**, 473–499.

MAZE BEHAVIOR OF THE RAT AFTER ELECTROSHOCK CONVULSIONS

BY EDWARD STAINBROOK

Duke University *

The experimental quest for an adequate theory which would make rational the empiricism of convulsive therapy as used in psychiatric treatment is probably best oriented around human subjects. Certainly there is now no lack of a human experimental population with which to work. A cursory general survey of the various aspects of psychological research on man which are applicable to the widespread use of therapeutic convulsions has been indicated elsewhere (8). Nevertheless, since the results of so many controlled investigations are in existence concerning the behavior of animals, particularly with reference to general learning and to the determinants and the cognitive structure of habits, psychologists and other workers interested in the rationale of convulsive therapy will want to study by animal as well as by human experimentation the complex of psychological happenings which is included in the effects of artificially produced convulsions.

Indeed, many contributions to this area of research are already being made. In a study of the influence of metrazol convulsions, Bunch and Mueller (1) found no significant differential effect upon the learning by rats of a 14 unit multiple T-maze. Heron and Carlson (2) substantially confirmed this observation, although Loken (4) indicated that both maze time and errors may be increased following these pharmacologically induced seizures. The differentiating ability of the dog in a conditioning situation is reported to be disturbed immediately following the administration of metrazol, but, according to Rosen and Gantt (5), discriminatory efficiency tends to return with recovery from the effects of the convulsion. Kessler and Gellhorn (3) have shown that convulsions tend to reactivate in the rat a conditioned response previously inhibited by non-reinforcement. Siegel (6) concludes that "the retention of a 'barely learned' simple response in the rat is not affected by a series of electroshock convulsions," and he similarly reports that the ability to learn a simple habit is also not affected by such convulsions. Stainbrook and Löwenbach (7) have indicated that in a simple water-maze a long

* From the Laboratory of the Department of Neuropsychiatry, Duke University School of Medicine.

series of either electroshock or noise-fright [1] convulsions does not alter the maze behavior of the rat insofar as error scores are concerned; time scores, however, are significantly different.

In the present study it was desired to find out what effect a long series of electroshock convulsions would have upon the rat's retention of maze-habits learned under the motivation of hunger and food-reward. The experimental emphasis was placed upon an adequate number of convulsions and upon the utilization of the usual maze-learning methods.

Methods

Twenty-eight animals of a black-hooded colony, developed from an original Lashley jumping strain, aged eight months, and evenly divided as to sex and as to behavioral reaction to the experimenter, were trained in a two choice-point, right-left T-maze to run for a Purina paste food-reward. Learning was considered well established when the rat made no more than three errors in 15 successive trials. Error scores as well as time spent in the maze and in the start box were recorded.

At the end of the learning period the animals were divided into two groups as evenly weighted with the specifications of the initial group selection as possible, with the exception that 12 of the animals were reserved for the control group and 16 were placed in the electroshock (ES) group because of the mortality expectancy for these latter animals. Each animal was placed in a separate cage and standard conditions of feeding, handling, etc., prevailed throughout the experiment. The ES animals were given one convulsion every day for 30 consecutive days by means of ear-electrodes, with an electrical tension of 85 volts applied for 180 milliseconds. The control animals were handled similarly except, of course, that the current was not passed after attachment of the electrodes.

At the end of the series of 30 convulsions for the ES group, all animals were allowed to remain without handling for the next 15 days, at the end of which time they were placed on the same fasting program as preceded the initial learning. The same observational routine of error and time scoring was followed while the rats learned the maze to the original overtraining of no more than three errors in 15 successive runs. An experimental day consisted of five maze-trials for each rat both in the initial and relearning periods.

Results

Fig. 1 shows the remarkably close approximation of the initial learning curves of the two groups for total maze time. Fig. 2 indicates total errors for the original learning periods. A point on the graphs represents the total time or the total errors for all animals in each group summed for the five runs in each experimental day.

The total time spent by the ES rats in the maze after the convulsive series is also shown in Fig. 1. This is plotted against the relearning time data of the control group. The total errors of both groups for each post-convulsive experimental day are shown in Fig. 2.

Strictly considered, a comparison of habit retention for the maze must be based upon only the first trial in the relearning period. It was here that the first difference in the behavior of the ES rats was

[1] Noise-fright is used to describe the reactions in the rat which are called 'audiogenic,' 'audioepileptic,' or 'abnormal behavior' by others. Such reactions may only rarely, in my experience, be properly called convulsions in the 'epileptic' sense (9).

demonstrated. Five of the 12 ES animals would not go through the wire re-trace barriers, and after two days' trial in the maze for 15 min. periods, which was marked by the rat's incessant activity in a small section of the maze to which it was restricted, the barriers were lifted and arranged so that they could be noiselessly and unobstrusively lowered after the rat had passed the various maze sections.

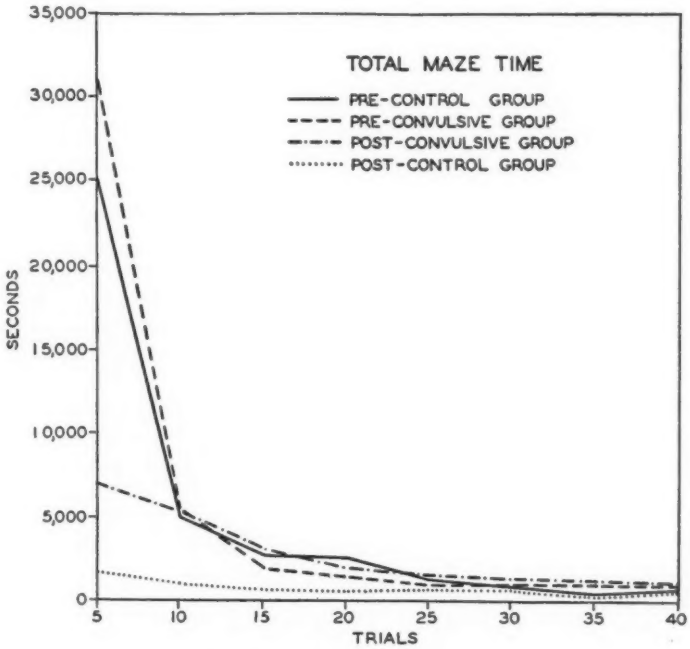

FIG. 1. Total time spent by all animals in a designated group in running the maze for each five trials of an experimental day. Note that relearning time scores of electroshock rats indicate maze familiarity.

Counting only the first completed trial for each rat, the mean time for the first relearning trial of all the control animals was 47 sec. For the ES rats the mean was 453 sec. Even though in both distributions there was considerable latitude of dispersion, the difference between these two means is statistically quite adequate for an hypothesis of essential difference. This difference is equal to 8.3 times the standard error of the difference. Similarly, the mean total time for the first five relearning trials was 158 sec. for the control group and 583 sec. for the ES rats. The standard error of the difference is exceeded 7.5 times by the difference between these means.

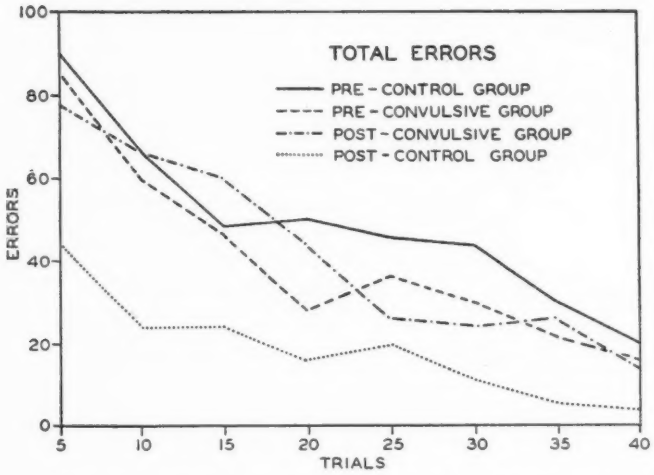

FIG. 2. Total errors made by designated animals for each five trials in learning and relearning maze. The relearning curve of the electroshock group, in contrast to significantly reduced relearning errors of control group, shows little evidence of maze habit retention.

After the second day the time scores of the two groups began to fall more and more within a mutual distribution area.

For the ES group the effects of maze habit retention can be seen only in the time scores (Fig. 1).

As may be seen in Fig. 2, the first five trials after the convulsive period summed to a total error score which very closely approximated the first five trials of the original learning period, and, indeed, the relearning curve for errors of the ES rats follows very closely the original learning curve. On the other hand, the relearning error curve of the control group (Fig. 2) was distinctly different both from the original learning curves of the two groups and from the ES relearning curve, indicating considerable retention of the maze habit by the control animals.

As described previously (7) the ES rats began to display 'abnormal' behavior after the second to fifth electroshock convulsion. While in the maze during the relearning period, these animals were easily disturbed by slight noises and gave evidence of being much more fearful and expectant of threat than were the control rats.

DISCUSSION

Obviously, there are several factors to be considered in the evaluation of the effect of electroshock convulsions upon habit retention in

animals. Quality and intensity of motivation, discriminative complexity, amount of overtraining, and recency of experience are the most important determinants of trace-structuring, activation, and persistency.

As has been indicated above, in a simple water-maze requiring only very easy orientation decisions, overtrained rats subjected to an even greater number of convulsions than the animals of this study made no more errors in the maze performance than are normally expected. Similarly, still unpublished data indicate that in a three choice-point water-maze, overtrained rats do not show any observable habit disorganization in maze trials on the days following the administration of 10 convulsions massed into a half-day schedule with a convulsion given every half hour. On the other hand, rats put into similar water-mazes immediately following either single or massed convulsions make errors for a number of trials which roughly corresponds to the number of convulsions given in the experimental session. There is manifest, therefore, a transitory disorientation effect upon the maze behavior of the rat following single and massed electroshock convulsions, even when the animals are greatly overtrained in the maze habit.

In the water-mazes, the 'temperamental' effects associated with electroshock convulsions do not usually have any significant influence upon the time taken by the rat to swim the maze on days when no convulsions are administered. Actually, the maze time may be reduced below normal values because of the apparently heightened vigilance of the animals. In the food-reward maze, however, running time is greatly increased for these ES rats and, as has been indicated in another paper (7), it was necessary to abandon the use of such a maze in studying behavior immediately following convulsions because the rat would simply remain immobile in the start box, sometimes for hours.

In the present study, 50 days elapsed before the animals were put back into the original maze situation. This was 20 days after the last convulsion. It is highly unlikely, therefore, that any immediate post-convulsive effects were then operative in the behavior of the ES rats. For these animals the only objective evidence of familiarity with the maze was seen in the time scores of the relearning as related to the initial learning time. The error scores indicated practically no retention of the maze habit. Before it may be concluded, however, that such findings point to an enduring disorganization of the once sharply defined cognitive structure of the maze habit, it would be necessary to rule out the possibility that the errors of relearning were conditioned by the 'emotional' behavior of the animals induced by the electroshock convulsions.

Summary

1. Twenty-eight rats which had learned a two decision-point, right-left T-maze under hunger and food-reward motivation were divided into two groups of 12 and 16 animals. One group was given one electroshock convulsion every day for 30 days, and both groups were put back in the maze 20 days after the last convulsion of the electroshock animals.

2. The only objective evidence of maze habit retention in the electroshock rats was seen in the relearning-time scores relative to the initial learning-time scores of the same group. The relearning-time scores of the experimental animals, however, were significantly greater than those of the control group.

3. Relearning error scores of the electroshock rats relative to initial learning errors of the same animals were not significantly different. Relearning error scores of the electroshock group were significantly greater than the relearning errors of the control group.

4. The possibility that the errors of relearning of the electroshock animals were conditioned by the 'emotional' behavior induced by the electroshock convulsions must be considered before it is concluded that a long series of electrically-induced convulsions effects an enduring disorganization of the finely discriminative cognitive structural-trace of a recent maze habit.

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References

1. Bunch, M. E., & Mueller, C. G. The influence of metrazol upon maze learning ability. *J. comp. Psychol.*, 1941, **32**, 569–574.
2. Heron, W. T., & Carlson, W. S. The effects of metrazol shock on retention of the maze habit. *J. comp. Psychol.*, 1941, **32**, 307–309.
3. Kessler, M., & Gellhorn, E. The effect of electrically and chemically induced convulsions on conditioned reflexes. *Amer. J. Psychiat.*, 1943, **99**, 687–697.
4. Loken, R. D. Metrazol and maze behavior. *J. comp. Psychol.*, 1941, **32**, 11–16.
5. Rosen, V. H., & Gantt, W. H. The effect of metrazol convulsions on conditioned reflex training in dogs. *Fed. Proc. Amer. Physiol. Soc.*, Boston, 1942, **1**, 74.
6. Siegel, P. S. The effect of electroshock convulsions on the acquisition of a simple running response in the rat. *J. comp. Psychol.* (In press)
7. Stainbrook, E. J., & Löwenbach, H. The reorientation and maze behavior of the rat after noise-fright and electroshock convulsions. *J. comp. Psychol.*, 1942, **43**, 293–299.
8. Stainbrook, E. J. A modified Rorschach technique for the description of transitory post-convulsive personality states. *Rorschach Res. Ex.*, 1941, **5**, no. 4, 192–203.
9. Stainbrook, E. J. A note on induced convulsions in the rat. *J. Psychol.*, 1942, **13**, 337–342.

AN ELECTRONIC INTERVAL TIMER

BY B. R. PHILIP

Fordham University

F. REINTJES AND R. T. WEIL, JR.

Manhattan College

Several electronic devices have been designed to give stimuli of different temporal lengths (**2, 4, 5, 6, 7**). They function effectively, but often the set-up is both bulky and complicated and additional equipment, such as batteries or power packs, is needed. Generally no provision is made for standardization of the intervals, except at the beginning and end of the experimentation.

A modification of the basic circuit of a relaxation oscillator which is here described has the following advantages:

1. One tube only is used, instead of a multi-tube set-up. The tube is a standard one, cheaper and more readily obtained than a thyratron which is often used in a circuit of this type.

2. Elimination of batteries or power packs is obtained by rectification of the a.c. line voltage, from the circuit arrangement.

3. Constant standardization of the temporal intervals is readily determined by the incorporation of a time clock, which functions whenever the circuit is in operation.

4. Provision is made for operating the stimuli from either a 6 volt or a 115 volt circuit, thus extending the possible uses of the instrument.

5. The apparatus is compact, portable, cheap and easy of construction from commercial parts. It is almost noiseless and requires no care once it is set up. In our laboratory two such instruments have been constantly in use for the past three years without requiring repairs.

The electric circuit of the timer (Fig. 1) consists of a 6N7 twin triode operating with an unfiltered half-sine voltage on each plate. The cathode current controls a Ward-Leonard single pole, single break, normally open sensitive relay. The voltage drop through the magnetizing coil provides part of the grid bias for the tube; additional bias is provided by R_1.

The relay used in this timing circuit has a coil resistance of 765 ohms and operates on a threshold current of 4.23 ma. d.c. Any relay having approximately these characteristics should be satisfactory. The contact rating should be at least 2.0 amperes a.c. at 120 volts.

R_1 is selected so that with S1 open the cathode current through the relay coil is insufficient to close the relay contacts. When S1 is maintained closed, the bias is removed from the grid, and sufficient current flows through the relay to close the contacts. C2 immediately begins to charge through R2–R14 at a rate determined by the time constant of the circuit. Ultimately, the increasing grid bias reduces the cathode current and the relay contacts open. C2 must be discharged by releasing the shorting key, S_1, before the cycle can be repeated.

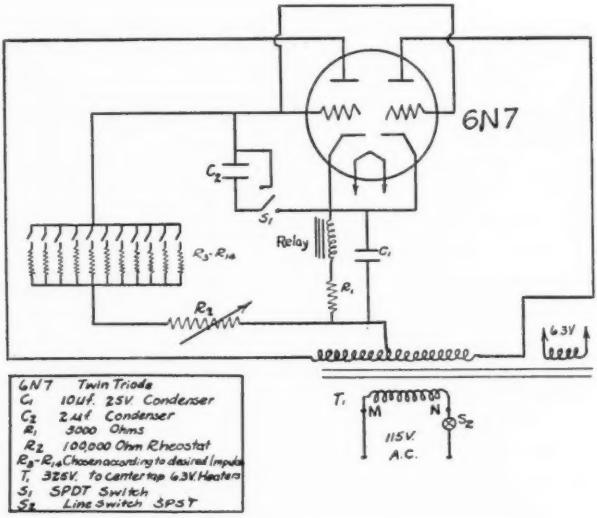

FIG. 1. Circuit diagram of electronic interval timer

The timer was arranged simultaneously to operate a lamp (or a buzzer) and an electric clock. The use of a simple single contact relay necessitated a careful polarization of these items in order to prevent a short circuit when operated from a grounded 120 volt 60 cycle a.c. system. The particular clock used was equipped with an electromagnetic clutch mechanism and a driving motor both operated from the a.c. line. By means of a 5 prong tube socket and a 5 prong bayonet plug proper polarization was obtained as indicated in Fig. 2. Examination of the circuit will show that the clutch mechanism coil is energized only when the relay contacts are closed. During this period the lamp or buzzer and clock are operating.

The use of electric clocks of a type other than that shown in the

accompanying diagram may introduce different polarization problems if the single contact relay is used.

The unit is assembled on a metal chassis base enclosed in a small metal cabinet. On the front of the cabinet are the controls, an on-off switch, an eleven point switch to select the appropriate resistor for the time interval desired, and a potentiometer (R_2) to permit slight variations in the circuit resistances.

At the back of the cabinet are the plug and socket connectors for the other instruments (clock, shorting key, lamp, buzzer). The

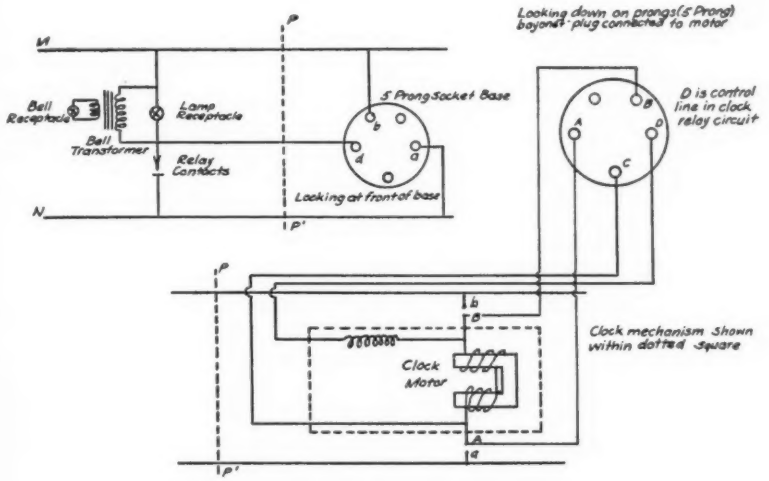

FIG. 2. Diagram for assembly of apparatus

MN_1—Connection points for control circuit. (See Fig. 1.) Polarized clock circuit to right of section line PP'. abd—Female connections in socket base. ABCD—Male connections in bayonet plug.

sockets for the clock and key are adapted for five and four prongs respectively, so that a wrong contact cannot be made, and proper polarization can be obtained.

The time intervals may be varied from a few hundredths of a second to 20 seconds by the selection of appropriate resistors, the exact values of which will depend upon the constants of the circuit. For the shortest times the resistors required will probably be of the order of 0.1 megohm, while the longest times will require resistors of the order of 20 megohms.

Electronic devices of this nature often show considerable variability, which may be due to several causes. There is a warming-up effect, principally due to temperature effects in the resistors. How-

ever, the variation thus caused is slight and readily stabilizes to a constant value if ventilation is adequate. As the tube deterioriates the values of the intervals may considerably diminish. When adequate attention is given to secure an efficient tube, no trouble is experienced on this score. Most of the variability of the intervals as measured by a Standard Electric Clock is often due to the clutch mechanism of the clock. As Dallenbach (1) has pointed out this variability is of the order of from 0.5 to 2 percent, and is greatest for the shortest intervals. That this variability may be brought within low limits may be seen from Table I, which is presented with the permission of Dr. Kowalski (3).

TABLE I

MEAN, SIGMA AND COEFFICIENT OF VARIABILITY FOR DISTRIBUTIONS OF STIMULUS DURATIONS

Mean Stimulus Duration in Sec.	σ Dist.	Coefficient of Variation
0.483	.0096	2.0
0.926	.0157	1.7
1.904	.0305	1.6
4.151	.0603	1.5
6.253	.0814	1.3
8.909	.1024	1.1
16.233	.1479	0.9

N = 840 at each point.

The length of the time intervals varies with the input voltage. However the timer will operate with a 10 percent fluctuation in voltage from 115 volts. A convenient way of avoiding this difficulty is to place a Variac in the 115 volt input line, and the Variac by voltage control may be used to adjust the intervals to the precise values required. This method is much simpler and more convenient than to attempt to secure the exact resistance necessary to secure a precise time interval.

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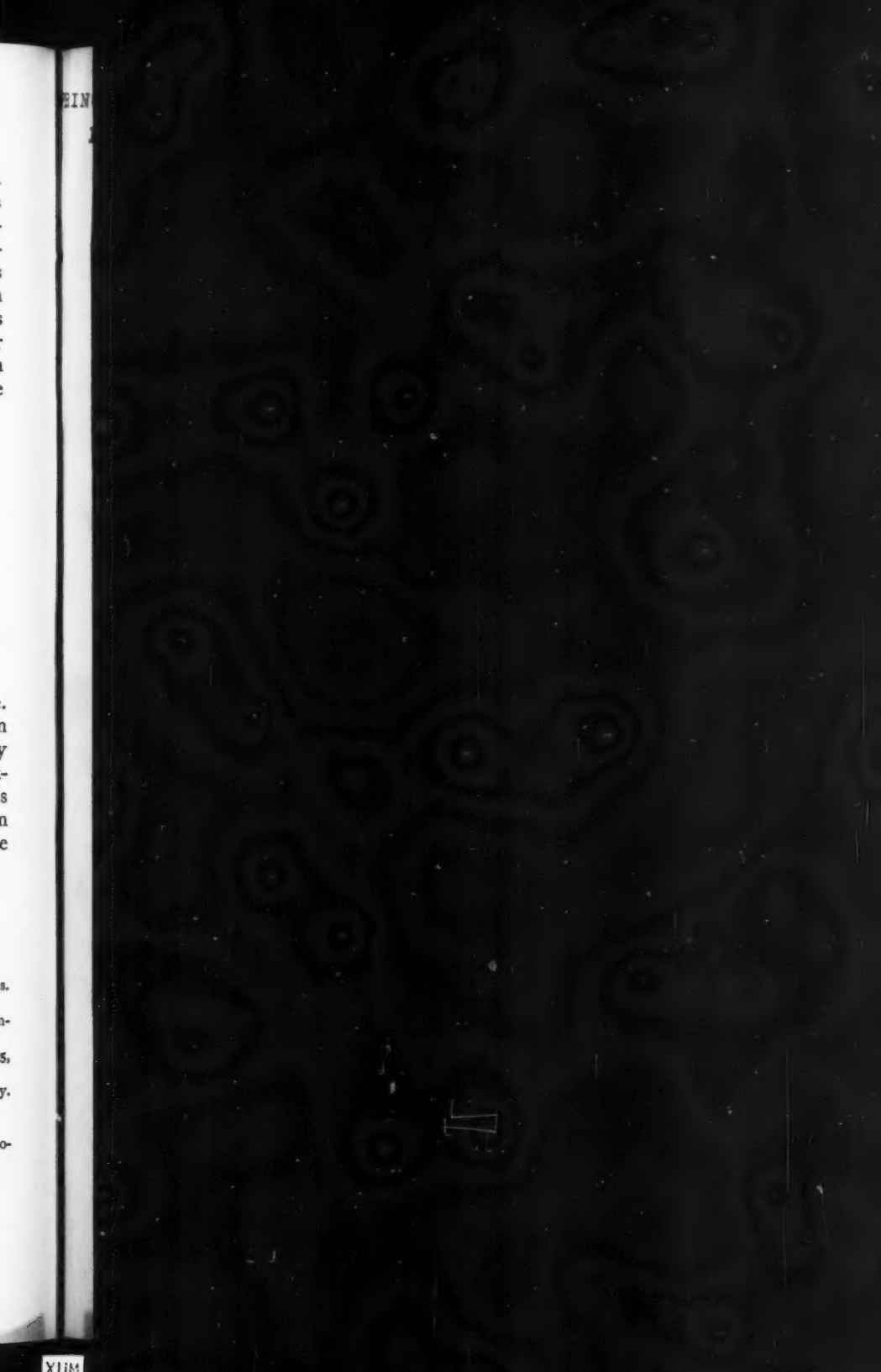
REFERENCES

1. DALLENBACH, K. M. Two new A.C. chronoscopes. *Amer. J. Psychol.*, 1936, **48**, 141–151.
2. KARSLAKE, J. S., & TIFFIN, J. Supplementary equipment useful in research on eye movements. *Amer. J. Psychol.*, 1939, **52**, 625–629.
3. KOWALSKI, W. J. The effect of delay upon the duplication of short temporal intervals. Unpublished doctoral dissertation. Fordham Univ., 1942.
4. MAEDER, W. D., & JENKINS, J. J. A condenser-charge timer. *Amer. J. Pscychol.*, 1933, **45**, 742–745.
5. THORNE, F. C. The psycho-physical measurement of the temporal course of visual sensitivity. *Arch. Psychol.*, 1934, **25**, No. 170. 134–25.
6. THORNE, F. C. A thyratron-tube chronaximeter. *Amer. J. Psychol.*, 1933, **45**, 515–517.
7. TOWNSLEY, R. R., & TREMBLE, O. T. An electrically timed exposure apparatus with chronoscope connections. *J. gen. Psychol.*, 1935, **13**, 446–471.